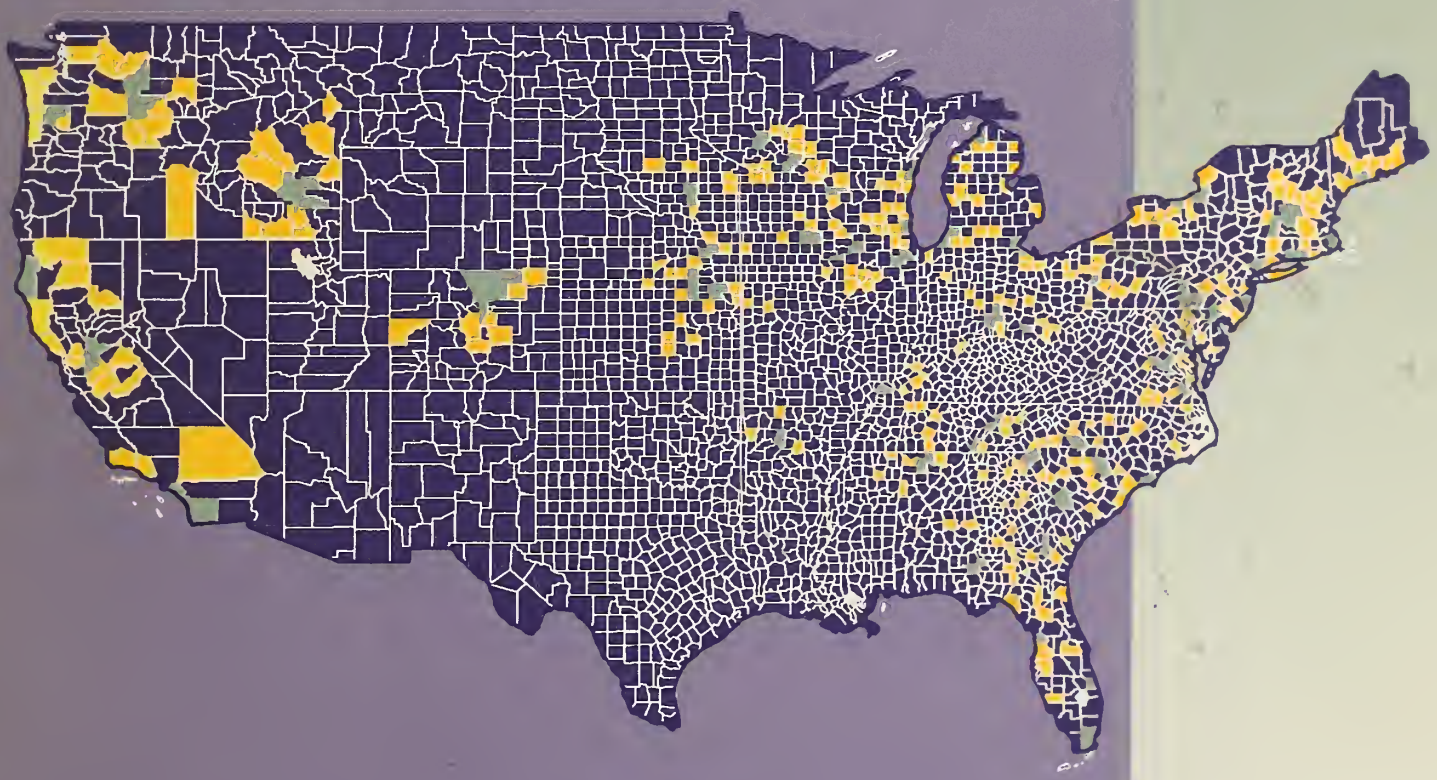
# Cancer in Populations Living Near Nuclear Facilities



Vol 1. Report and Summary

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# CANCER IN POPULATIONS LIVING NEAR NUCLEAR FACILITIES

## VOLUME 1 - REPORT AND SUMMARY

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The detailed plan for the study was evaluated by an expert team of non-government scientists reviewing the intramural research activities of NCI's Radiation Epidemiology Branch. Subsequently, a special advisory group of non-government scientists was established by the Board of Scientific Counselors of the Division of Cancer Etiology to provide guidance and oversight for this project. We are especially grateful to the members of this committee for their many helpful suggestions for improvement. The list of members of the committee and their consensus statement concerning this project can be found on the following pages.

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# CONSENSUS STATEMENT OF THE AD HOC ADVISORY COMMITTEE FOR THE STUDY OF CANCER IN POPULATIONS LIVING NEAR NUCLEAR FACILITIES

The Committee has reviewed the data assembled by the authors of this report, the methods employed to obtain the data, the form of the analyses and the inferences that have been made based on those analyses. Three formal meetings were held in 1989 and 1990, at which the progress of the survey was critically reviewed. The Committee was also asked to provide suggestions for additional research, if any seemed warranted.

The NCI survey utilized existing sources of data so that it could be completed in a time frame that was relatively short for a survey of such magnitude. However, this resulted in certain limitations, which are discussed below.

The survey examined deaths attributed to leukemia or other cancers in the study counties, that is, counties that encompass or are near nuclear facilities. All commercial nuclear electric plants that were in operation by 1981 were included, as were ten facilities that engaged in nuclear fuel fabrication or reprocessing, isotope separation or other activities that use radionuclides.

Although all forms of cancer were studied, the survey appropriately emphasized leukemia since, of all fatal forms of cancer, leukemia shows the greatest relative increase following exposure to ionizing radiation, and increases in leukemia had previously been reported among children who lived near certain British nuclear facilities.

The Committee believes that the statistical treatment and interpretation of these data are quite satisfactory. Comparisons of study and control counties exhibit substantial variation, as should be expected, because the matching cannot remove all variation due to demographic factors. Properly taking this into account, there is no evidence of systematically higher cancer risks in the study counties. Moreover, even the highest relative risks for individual facilities were compatible with the general level of variation seen.

In this regard, the comparison of cancer rates both before and after nuclear facilities began operation was especially informative. Overall, the relative risks of leukemia and other cancers appeared to be slightly higher before reactor startup than after, providing no evidence that environmental pollution attributable to the facilities might be causing a substantial increase in cancer risk in the study counties.

The Committee concludes that the survey has produced no evidence that an excess occurrence of cancer has resulted from living near nuclear facilities. Further, measurements of radioactive releases from nuclear facilities indicate that the dose from routine operations is generally much below natural background radiation, and hence may be unlikely to produce observable effects on the health of surrounding populations.

However, there have been releases from some facilities, such as at Hanford, that were high, and there continues to be widespread public and scientific concern, in part raised by unexpected findings in the United Kingdom that have not yet been explained fully. Consideration should be given, therefore, to further investigations and monitoring, including attention to the following points:

- The present study is based on data from counties, some of which are very large, and it is possible that any effects in the immediate vicinity of the facilities escaped detection because they were diluted by the larger populations more remote from the facilities. Surveys of cancer occurrence around certain facilities using smaller population groupings, such as census tract data, may be useful.

- Many of the nuclear electric plants have come into service only in the past few years, and not enough time may have passed for possible radiogenic effects to have appeared. Thus, cancer mortality rates in areas around nuclear facilities should continue to be monitored.

- Data on cancer incidence, rather than mortality, would permit a more sensitive assessment of possible increases in cancer. In this study, incidence data were available for only four facilities. In recent years, however, cancer registration data, some of which are of good quality, have become available in many states and the possibility of utilizing such data should be explored.

- Case-control studies of cancer incidence, in small areas around nuclear facilities and in control areas, are potentially informative. Such studies, however, are not without methodologic limitations, and, in addition, make very heavy demands upon both time and resources. They should, therefore, be undertaken only after careful consideration.

- The recent findings by Gardner and co-workers, showing that the risk of leukemia in children living near the Sellafield nuclear reprocessing plant in Britain was higher for those children whose fathers had been occupationally exposed to ionizing radiation, are potentially of great importance (Br Med J 300:423, 1990). An attempt to replicate such findings would be of interest.

- To ensure that effort and resources are not duplicated, and to ensure that methodologies are compatible so that the results from different studies can be combined, there should be close cooperation among state health departments, federal agencies, academic institutions, and other groups that are presently conducting or planning detailed studies of the populations near individual facilities.

July 11, 1990

# CANCER IN POPULATIONS LIVING NEAR NUCLEAR FACILITIES

## ABSTRACT

Recent studies from the United Kingdom have reported increases in mortality from leukemia among young persons, especially under age 10, living near certain nuclear installations. The reasons for this pattern are not clear and there were no corresponding increases in total cancer mortality. Because of concerns raised by these data, a survey of cancer rates was conducted in populations living near nuclear facilities in the United States. The study encompassed all 62 nuclear facilities that went into service prior to 1982, including commercial electricity-generating plants and major Department of Energy facilities engaged in nuclear fuel reprocessing, isotope separation or other activities involving radioactive materials.

Over 900,000 cancer deaths occurring between 1950 through 1984 in 107 counties with nuclear installations and certain adjacent counties in the United States were evaluated. For counties in two states, cancer incidence data were also available and evaluated. Each study county was matched for comparison to three similar "control counties" in the same region. Over 1,800,000 cancer deaths occurred in these control areas. There was no evidence to suggest that the occurrence of leukemia or any other form of cancer was generally higher in the study counties than in the control counties. For childhood leukemia, the relative risk comparing the study counties with their controls before plant startup was 1.08, while after startup it was 1.03. For leukemia at all ages, the relative risks were 1.02 before startup and 0.98 after startup.

The survey results showed that some of the study counties had higher rates of certain cancers, and some had lower rates, either before or after the facilities came into service. The observed comparisons provided no evidence of any cause-effect relationship between particular facilities and cancer occurrence in nearby populations. The study is limited by the correlational approach and the large size of the geographic areas (counties) used, and of course it cannot prove the absence of any effect. However, if any excess cancer risk was present in U.S. counties with nuclear facilities, it was too small to be detected by the methods employed in this survey.

## SUMMARY

A survey of mortality from leukemia and other forms of cancer in the environs of 62 nuclear facilities in the United States has been made. More than 2,700,000 certificates of death due to some form of cancer during the period 1950-1984 were analyzed. Included in the survey were 52 commercial electricity-generating nuclear facilities that had gone into service by the year 1981 and ten other facilities that reprocessed nuclear fuel, produced radioactive isotopes, separated isotopes, or carried out other activities involving radioactive materials. Counties in which nuclear facilities were located and certain adjacent counties were designated "study counties". Three "control counties" were matched to each study county for comparison. Over 900,000 cancer deaths occurred in the study counties and over 1,800,000 in the control areas. Cancer incidence data were also obtained for the counties around four facilities in two states.

This survey was initiated following a report published by the British Office of Population Censuses and Surveys (OPCS) on cancer risk in the vicinity of nuclear facilities in England and Wales. The most striking finding of the British survey was the occurrence of excess deaths from leukemia in young persons, especially those under age 10, in the vicinity of one particular fuel reprocessing plant (Sellafield). Overall, however, there was no evidence to support a general increase in total cancer mortality near nuclear installations in the United Kingdom, and the reasons for the elevation of childhood leukemia were not clear.

In the present study, standardized mortality ratios (SMRs) were calculated for sixteen classes of cancer for each study area and for the associated control areas for five-year periods both before and after the startup of the facility in question. For each cancer, both SMRs and relative risks (RRs) were calculated, permitting comparisons between the study and control areas before and after the facilities came into service. Similarly, comparisons of cancer occurrence were made separately for the study and control areas before and after the facilities went into service. Five different age groups as well as all ages combined were examined. The SMRs provided a basis for comparison with rates for the United States as a whole. Relative risks were calculated as ratios of SMRs. Comparisons were made for each facility and also for combined groups of facilities: all Department of Energy (DOE)

facilities; the early electric power plants (those that went into service before 1970); those that started up between 1970 and 1974; and the later plants that started between 1975 and 1981.

Many thousands of comparisons were tested explicitly for statistical significance. Hundreds of the tests turned out to be "significant" in a technical sense, marking comparisons that indicated either excesses or deficits of cancer risk. To help distinguish excesses possibly indicative of adverse health effects attributable to the facilities from those that resulted from mere chance or from variation resulting from other environmental, industrial, or local factors, several questions were asked:

- Were the differences between study and control areas present before the facility began operations or did they occur only after startup?

- Was the cancer rate in the study area "significantly" larger than that in the control area only because the control area rate was abnormally low, while the study area rate was not significantly different from the U.S. rate?

- Was there an increase in the SMR for the study area after the facility began operations? If there were increases in cancers other than leukemias in the study area, did they take place at least ten years after startup as would be expected?

- Were increases identified for those forms of cancer known to be especially susceptible to induction by radiation (i.e., leukemia, female breast cancer, and lung cancer)?

So many comparisons have been made that even the few "significant" test results that successfully passed these tests of credibility may nevertheless represent chance occurrences. Further, although control counties were matched as closely as possible to the

study counties, differences in other important variables, apart from the presence of a nuclear facility, probably exist that could have contributed to any differences in cancer rates.

Of the nearly 900,000 cancer deaths that were evaluated around U.S. nuclear installations, 350,000 occurred before the plants became operational and 530,000 after startup. These numbers include 37,500 deaths attributed to leukemia. Overall, and for specific groups of nuclear installations, there was no evidence to suggest that cancer mortality in counties with nuclear facilities was higher than, or was increasing in time faster than, the mortality experience of similar counties in the United States. Data on all 1,394 deaths due to leukemia in children below age 10 also did not suggest an overall increased risk in areas with nuclear installations.

On examination of the data for individual facilities, only the incidence data for the area around the Millstone nuclear power plant in New London County, Connecticut, showed a significantly increased RR of leukemia at ages 0-9 years. However, the significance of the difference was largely attributable to very low leukemia rates in the control counties. No other excesses of deaths from childhood leukemia were found that could be linked to any of the nuclear facilities. Further, three study areas (San Onofre, Quad Cities, and Vermont Yankee) were marked by significant deficits in the RR for leukemia deaths at ages 10-19. No excesses in mortality from any form of cancer other than leukemia, or from leukemia in any group over 10 years of age, were identified that could, plausibly, have resulted from the operation of any facility or set of facilities.

Radiation releases from nuclear power stations are reported to be quite low, delivering to any person, at a maximum, less than 5% of the radiation exposure that is normally received from natural background sources, such as radionuclides in the earth and cosmic rays. Such low levels would not be expected to result in detectable increases in childhood leukemia or other cancers. On the other hand, certain facilities, such as Hanford, are known to have released more than average amounts of radiation into the environment.

An apparent excess risk observed around any facility may be a chance observation or, if real, might result from excessive but undetected radioactive emissions from the plant, from exposures to chemical effluents, or from other circumstances that may be peculiar to

individual areas in comparison with their control counties. Mortality from leukemia was examined for populations living near 62 facilities for each of six age groups, so it was not unexpected to find, by chance, one or more "statistically significant" excesses and deficits. Finally, some excesses in risk may result, not from the operation of the facilities themselves, but from the large population movements stimulated by the building of large industrial complexes in rural areas.

The survey, based as it was on existing mortality and incidence data, suffers from a number of weaknesses: for most of the facilities only mortality, not incidence, data were available; data were not available for areas smaller than entire counties; and the causes of death were obtained from death certificates and are, therefore, of variable quality. Although all of the DOE facilities went into service more than 35 years ago, many of the commercial nuclear electric stations began service relatively recently and not enough time may have passed to allow for the expression of cancers that may still have been latent in 1984.

The strengths of the survey include the large number of facilities studied, the selection of control counties for comparison purposes, the evaluation of risks before and after reactor startup, and the availability of 35 years of mortality data for each county included. Further, the method used (correlation analyses of county mortality data) has been successful in the past in pointing to such carcinogenic hazards as arsenical pollution from metal smelters, and asbestos exposures in shipyard workers.

From the evidence available, this study has found no suggestion that nuclear facilities may be linked causally with excess deaths from leukemia or from other cancers in populations living nearby. Studies in the United Kingdom had found increased mortality from leukemia in children near two nuclear fuel reprocessing complexes and two nuclear weapons plants. Examinations of similar installations in the United States failed to find such increases. The study, of course, cannot prove the absence of an effect, and its findings must be viewed in the context of its ecological approach and the relatively large geographic areas (counties) used in the study. It can be said, however, that if any excess cancers have occurred in counties with nuclear facilities, the number has been too small to detect by the methods employed.

## INTRODUCTION

Nuclear facilities are widely distributed throughout the United States. Although there have not been, in this country, large-scale accidental releases such as the one that occurred at Chernobyl, questions continue to be raised about the possibility of adverse effects upon health resulting from less dramatic failures such as the release at Three Mile Island, or even from routine operation of these facilities and the disposal of their radioactive waste. In addition, some individual facilities, such as Hanford and Rocky Flats, are known to have released higher than average amounts of radiation into the environment during certain periods of operation. The issues involved are complex and this report addresses only one specific question: Is there evidence, at the level of available data, that residents of counties near nuclear facilities are at increased risk of death from cancers known to be related to exposure to ionizing radiation?

The discovery of nuclear fission and the subsequent development during World War II of fission reactors and then fission bombs culminated, for the first time, in the exposure of large numbers of people to man-made ionizing radiation other than that given for some medical reason. The Atomic Energy Commission recognized that the many thousands of atomic bomb survivors exposed in Hiroshima and Nagasaki represented a large population whose radiation exposure was not the result of medical treatment and who had been subjected to a wide range of radiation doses, from the trivial to the fatal. It had been learned from studies on animals that x-rays could cause cancers that had their onset only after a long delay. The Commission supported long-term studies of the survivors in Japan, which were initiated by the National Academy of Sciences in 1948. From these and a number of other studies, including patients exposed to x-rays for diagnosis or therapy, miners exposed to high concentrations of radon gas, and radium dial painters and radiologists exposed in the course of their work, it was learned that radiation exposure leads to an increased risk of cancer. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1977) stated: "It is generally accepted that cancer is the major long-term somatic effect of radiation on human beings."

The present report does not discuss such topics as the measurement of ionizing radiation, the sources and magnitude of the exposure of the population of the United States

to natural or man-made radiation, or scientific knowledge concerning the process of radiation carcinogenesis. Interested readers are referred instead to authoritative discussions of these topics contained in references BEIR (1990), UNSCEAR (1988), and NCRP Reports No. 92 and 93 (1987).

While much is known about the induction of cancer by radiation, there are several questions of considerable importance economically and to the public health that are still open. Although it seems likely that exposure of a population to single radiation doses of as much as 0.1 Gy (10 rad) (about 100 times the average annual dose from natural background radiation) or more will cause some excess cancers, it is uncertain whether this is true for much smaller doses, especially if they are received at a very low rate over a protracted time. It is evident that if a particular radiation dose will cause an average of, say, four extra cancer deaths in 10,000 persons over their remaining lifetimes, that fact could not be demonstrated in an epidemiological study. To follow a human population for sixty years (which would be necessary) would require several successive dedicated investigators and a long-term institutional commitment that would be difficult to sustain. Even if that could be done, the four extra deaths could not be distinguished from the approximately 2,000 deaths from cancer that would develop from other causes in a group of 10,000 persons.

There is less difficulty about assessing the carcinogenic potential of radiation following large doses -- of the order of 0.5 or 1 Gy (50 to 100 rad). Although questions remain about the sensitivity of specific tissue, the role of age at exposure, and the course in time of the cancer excess, the general picture and the approximate magnitude of the risks are fairly well known (BEIR, 1990). The magnitude of the cancer risk following low doses, however, particularly low doses at low-dose rates, must be inferred from high-dose studies. Whether the low-dose risks are strictly proportional to the dose received or are larger or smaller than might be inferred from the high-dose studies is uncertain and is a matter of scientific debate.

Since it is well known that radiation can cause cancer, many people are unwilling to be subjected to any possibility of exposure except for medical diagnostic or therapeutic reasons. Public concern about radiation, in particular about exposures that might result from proximity to a nuclear facility, is not related to quantitative information regarding the

magnitude of the exposures or the attendant risks, or to how they compare with other radiation exposures, including those from natural background. Annual doses received by persons living in counties with nuclear installations, for example, are much less than 0.1 mGy (0.01 rad), or a small fraction of the radiation the population is estimated to receive each year from natural background, such as cosmic rays and terrestrial sources (NCRP Report 92, 1987; UNSCEAR, 1988). Such levels are much lower than those expected to cause a detectable increase in childhood leukemia (Darby and Doll, 1987).

There is the possibility of a catastrophe such as the one at Chernobyl and which, for a time, threatened at Three Mile Island. The Chernobyl accident resulted in large radiation exposures to thousands of people. In contrast, the accident at Three Mile Island did not result in large exposures despite the initial fears. Apart from the danger of accidents, there is the question of the radiation doses and the consequent risks that may result from nuclear facilities while they are operating normally. Measurements are made both inside the facilities and in their environs to assure that emissions, both gaseous and liquid, are low and to ensure that radiation exposures to the public are so small as to pose no measurable risk. Nevertheless, there are, from time to time, releases, some purposeful but others unanticipated, and questions remain as to whether residence in the vicinity of a nuclear facility imposes a detectable increased risk of cancer. Recently, for example, concern has been raised about the health of residents near Hanford who may have been exposed to relatively large releases of radioactive iodine.

A number of studies about cancer risk from living near nuclear facilities have been reported, notably in Great Britain. Gardner (1989) provides a review of the various British studies. Some studies have identified excess cancers, particularly leukemias, in the vicinity of nuclear facilities while others have not:

- Baron (1984) examined time trends in standardized mortality ratios[1] (SMRs) in local areas around 14 British nuclear facilities, eight of which are power

[1]The standardized mortality ratio for an area is the ratio of the actual number of deaths that occurred to the number that would have occurred if the death rates in the area had been equal to the corresponding national rates. Standardized registration ratios, or SRRs, pertain to the number of cases diagnosed and registered.

generating plants. Scattered instances were found in which rates for particular cancers increased after the startup of a facility. However, increased leukemia was not identified from the mortality data in the area around the Windscale (Sellafield) reprocessing plant.

- Following a 1983 television documentary that reported an increased incidence of leukemia in children in the village of Seascale, near the Sellafield reprocessing plant, the British Government commissioned an independent advisory group to investigate the findings. The Black report concluded that there was an increased incidence of lymphoid leukemia in children (4 observed cases vs. 0.25 expected) in the area around Sellafield (Black, 1984; Craft et al.,1984).

- Gardner and colleagues (1987a,b) studied the occurrence of leukemia in children born to mothers who resided in Seascale. They found excess leukemia mortality that was limited to the children who had been born in Seascale (5 observed deaths vs. 0.53 expected) and did not occur in children who had been born elsewhere but attended school in Seascale (0 observed vs. 0.54 expected). A later case-control study showed that the excess was in children whose fathers were employed at the Sellafield reprocessing plant and who had received external occupational exposures of more than 100 millisieverts (10 rem) before the conception of the child (Gardner et al., 1990a,b). The authors hypothesized that exposure of fathers to ionizing radiation prior to conception was related to development of leukemia in their offspring. There were four such children; three of them, however, lived less than 5 km from the Sellafield plant so it is not easy to disentangle the risks that may have resulted from residence in close proximity to the plant from those that may have been associated with the fathers' occupations, including their exposures to radiation. Ongoing case-control studies around other nuclear facilities in the United Kingdom should provide additional

information concerning the likelihood that preconception radiation played a role in the reported clusters of leukemia.

- Heasman and colleagues (1986) surveyed cancer registration data in the area around the Dounreay facility, located on the north coast of Scotland. They found that in the years 1979-1984 five cases of leukemia in persons under age 25, of whom 4 were below 15, were registered in those who lived within 12.5 km (8 mi) of Dounreay. This contrasted with only 0.51 expected cases and represented a highly significant excess. The facility began operation in 1958 but no cases of childhood leukemia occurred in the years 1968 through 1978.

- Darby and Doll (1987) reviewed both the registration (incidence) data on leukemia in persons under age 25 who lived within 12.5 km (8 mi) of Dounreay and mortality data in the vicinity of the Sellafield (Windscale) reprocessing facility. Childhood leukemia was increased in the vicinity of both plants, but the authors were unable to attribute the observed increases to any of the possible causes that they considered. Radiation exposure, whether external or internal, by inhalation or ingestion, was considered far too small to have caused the excess risk.

- Roman and colleagues (1987) concentrated their attention on leukemia incidence among children under the age of 15 who lived in health authority areas including, or adjacent to, three nuclear facilities in England (none of which were electricity-generating plants). They found significantly increased standardized registration ratios (SRRs) for children under five years of age who lived in electoral wards that had at least half of their area within 10 km (6 mi) of one of the three nuclear facilities (Atomic Weapons Research Establishment, Aldermaston; Royal Ordnance Factory, Burghfield; and the U.K. Atomic Energy Authority establishment at Harwell).

- Ewings and colleagues (1989), using English cancer registration data, found increased SRRs for leukemia and non-Hodgkin's lymphoma among persons under age 25 who lived within 12.5 km (8 mi) of the Hinkley Point nuclear power station.

- Forman, Cook-Mozaffari and colleagues (1987) have published the results of two different studies that examined cancer mortality and incidence in populations living near nuclear installations in England and Wales. The first, done in collaboration with the Office of Population Censuses and Surveys (OPCS), examined both SMRs and SRRs for cancer in Local Authority Areas (LAAs) containing or near 14 nuclear facilities, six electricity-generating plants and eight others. These LAAs were compared with matched areas at larger distances. On examination, the authors concluded that there was too much variation in the quality of the registration (incidence) data to warrant confidence in the results and relied principally on the mortality data to support their conclusions. Many different forms of cancer were analyzed in relation to three age groups. The conclusions were that, for those under 25 years of age, deaths from lymphoid leukemia and brain tumors were more frequent around some of the installations. The effect was even stronger for children below 10 years. Although some other differences were observed in particular age groups, the authors considered them likely to be due to chance. They were, however, unwilling to dismiss the excess of childhood leukemia as due to chance.

  The authors were troubled by the fact that many of the apparent excess cancer rates in the study areas were elevated because the rates were unusually low in the control areas, and there was evidence that cancer registration was less complete in some areas than in others. Accordingly, in a second study, rates in the study areas were compared with rates for the entire population of England and Wales, both with and without adjustment for such factors as social class, rural/urban status, population size and Health Service region (Cook-Mozaffari et al., 1989a). It was concluded that there was excess

leukemia mortality among persons under age 25 in districts with some of their population within ten miles of a nuclear facility. No other cancer appeared to be increased except, possibly, Hodgkin's disease in the young.

- Cook-Mozaffari and colleagues (1989b) then reported a study in England and Wales of residents of areas where construction of nuclear power stations had been considered, or where they had only recently been built. They found excesses of childhood leukemia and Hodgkin's disease similar to those that they had previously identified for areas with operating nuclear facilities. They concluded that the unexpected increases in some childhood cancers around nuclear installations are likely to be due, not to environmental radiation pollution, but rather to other risk factors, as yet unidentified.

- The Committee on Medical Aspects of Radiation in the Environment (COMARE) has issued three reports (1986, 1988, 1989) that summarize many of the studies in Great Britain. The Committee concluded that there were elevated registration rates for leukemia and for some other childhood cancers among children below five years of age in areas within 10 km of the Aldermaston or Burghfield facility, but not near Harwell. It was concluded that "...atmospheric discharges are much too low to account for the increase in childhood cancer incidence..." and it was considered to be "most unlikely that the liquid discharges ...could account for the observed increase in childhood cancer incidence...." The Committee also found the incidence of childhood leukemia to be increased in the vicinity of the Dounreay plant; such an increase had already been demonstrated for Sellafield.

- Kinlen (1988, 1989) has suggested that the increased incidence of childhood leukemia found in the vicinities of Sellafield and Dounreay may have resulted from large population influxes. Population changes in a relatively short time to a previously sparsely populated area, may have introduced contagions that were leukemogenic to which the native population had little immunity.

- Clarke and colleagues (1989) examined leukemia mortality and incidence among children 0 to 4 years old who lived in the vicinity of nuclear power generating stations; uranium mining, milling and refining facilities; or nuclear research installations in Canada. They found no significant excesses or deficits of leukemia with respect to any or all of the different kinds of facilities.

- Dousset (1989) reviewed mortality data in the immediate vicinity of the La Hague nuclear facility, a French reprocessing plant, and in the Département in which it is situated. No excess mortality from leukemia or other cancers was found in the Département as a whole (la Manche), or in the much smaller "canton" of Beaumont-Hague, almost all of which is less than 10 km distant from the plant.

- Viel and Richardson (1990) analyzed data on mortality from leukemia during 1968 to 1986 in persons under 24 years of age who lived near the La Hague plant. No excess leukemia mortality was found (21 deaths vs. 23.6 expected based on age-specific death rates for the Département de la Manche).

- Enstrom (1983) studied mortality from cancer in Orange, Riverside and San Diego counties. The San Onofre power station is located in San Diego County, near the Orange County line. No effect on overall cancer mortality rates was seen in the three-county area, nor was there any evidence of increased mortality below age 20 from leukemia in the entire area, within 25 miles, or within 10 miles of the power plant.

- Stebbings and Voelz (1981) examined both mortality and incidence data from the New Mexico Tumor Registry for Los Alamos County, New Mexico, where the Los Alamos and Sandia National Laboratories are located. They found a suggestive excess mortality from leukemia, but there was no parallel

increase in leukemia incidence. There were suggestive excesses in neoplasms of the reticuloendothelial system in the early years and of the colon and rectum; the latter was thought to be explainable in terms of socioeconomic factors. The incidence of leukemia in children was not reported.

- Clapp and colleagues (1987) reported an excess incidence of leukemia in five Massachusetts towns near the Pilgrim nuclear power plant. Unlike the British findings, the excess was greatest for myelogenous leukemia in adult males (13 cases observed vs. 5.2 expected) but not in females (6 cases observed vs. 4.8 expected) or children. A subsequent analysis by Poole and colleagues (1988), however, did not appear to confirm these observations.

- Crump and colleagues (1987) examined the patterns of cancer incidence in the Denver metropolitan area because of concerns about cancer in relation to the Rocky Flats facility and possible environmental contamination with plutonium. They concluded that local area variations in cancer incidence rates could be explained best by closeness to the center of the city of Denver, an "urban factor". After the "urban factor" was taken into account, correlations of cancer incidence with proximity to Rocky Flats largely disappeared.

- Goldsmith (1989) observed that mortality from leukemia among children below age 10 was significantly increased in counties near the Oak Ridge, Tennessee and Hanford, Washington plants during the decade 1950-1959, but not thereafter. Milham (1989), however, pointed out that, at least in the case of Hanford, the adjacent counties had first large population (and birth) increases, and then decreases, during the decade of the 1950s and that rates based on interpolation of population numbers from 1950 to 1960 seriously underestimated populations and therefore overestimated rates.

Those investigators who found excess cancers in the proximity of nuclear facilities considered them not to be explainable as a consequence of the radioactive emissions reported for the facilities on the basis of current ideas about the magnitude of the leukemia risk per unit dose. They did, however, raise questions that require further investigation. The National Cancer Institute decided, therefore, to utilize available data to examine systematically the question in the United States.

It was decided to cast the net widely -- to utilize the available data on deaths from cancer by county and to use cancer registration data where they were available and of uniformly good quality. Data for each individual facility were examined, since it could not be expected that every facility would pose the same risk to the surrounding population. Facilities vary by type (whether electricity generators or other), age, power output and, not least, the experience and dedication of their operators. Therefore, it might turn out that for some plants, but not others, excess risks of cancer would be found. Alternatively, if particular facilities pose small, but not zero, risks that are not significant individually, perhaps by combining facilities the numbers might be increased to the point where the risk becomes visible. Accordingly, data for individual plants and for various combinations of facilities, including the entire set, were examined. Since the excess risks found in the United Kingdom occurred primarily around facilities other than nuclear power stations, data for the DOE installations of similar type were scrutinized with special care.

## METHODS

### SOURCES OF DATA

#### Mortality Data

This study is based on counties that contain, or are proximate to, nuclear facilities, contrasted with control counties. In the United States, counties are the smallest areas for which there are available on a national level both population estimates and annual counts of the number of deaths for specific causes of death. Mortality data were obtained from the National Center for Health Statistics in the form of a public use tape that shows, for each cause, the annual number of deaths by county, sex, race and 5-year age group. Estimates of annual county populations by sex, race and age group for the years 1950-1969 were obtained by linear interpolation in decennial census counts, as described by Riggan et al. (1983). For the period 1970-1984 the population estimates were prepared by the Bureau of the Census utilizing, not only the decennial censuses, but mid-decade sampling and data concerning school enrollment, public assistance programs and immigration records. The annual age-specific population estimates in 1950-1969 for counties that had much in- or out-migration may be in error as a result of the linear interpolation used for those years.

Cancer deaths have been analyzed with respect to 16 (sometimes overlapping) groups of causes. Appendix Table 1 shows the causes and their definitions according to the four versions of the International Classification of Diseases (ICD) that were in use during the period 1950-1984.

Although many forms of cancer can be induced by radiation, leukemia is the kind most readily identified as a radiation effect (BEIR, 1990). It was important, therefore, to examine carefully deaths from leukemia, and, especially in view of the reports from the United Kingdom, leukemia in children. Although chronic lymphatic leukemia is the one kind of leukemia not induced by radiation (BEIR, 1980), it is extremely rare as a cause of death in persons under 40 years of age (NCI, 1981). With few exceptions, leukemia in children is acute, and usually lymphatic. The ability of physicians to discriminate among the various subtypes of leukemia, especially childhood leukemia, has increased greatly in recent years. In the 1950s it was difficult to distinguish accurately between different forms

of acute leukemia and, in fact, the versions of the ICD that were in use through 1967 provided only for the category 204.3, "Leukemia, acute, unspecified." Accordingly, only the rubric "leukemia" has been employed.

Since multiple myeloma has been reported to be increased following radiation exposure, deaths attributed to that disease were examined, as were deaths from lymphoma, separated into Hodgkin's disease and "other" lymphoma.

Malignant neoplasms other than leukemia or those of the lymphatic and hematopoietic systems have been categorized in ten rubrics plus benign and unspecified neoplasms, in addition to the total. Because for death certificate data there is often uncertainty about the primary site of cancers of the gastrointestinal system, especially of the liver, the total for all digestive organs has been examined in addition to three specific sites: stomach, colon and rectum, and liver. The female breast is fairly sensitive to radiation carcinogenesis, as is the thyroid gland. The brain and other central nervous system tissues have been reported in some series to be sites of excess cancers, and so were also included. The category "brain tumor" is sometimes listed as the cause of death on death certificates; such deaths were ascribed to "neoplasms of unspecified nature" by the ICD. These deaths have been included, together with deaths ascribed to "benign tumors of the brain", under the rubric "malignant neoplasms of the brain and other central nervous system (CNS)".

Radiation-induced leukemia has been reported to occur as soon as two years after exposure. If emissions from a nuclear facility are responsible for an increased occurrence of leukemia, excess cases might be expected to be detected within the first five years after the startup of a nuclear facility or, of course, at any time thereafter. Other forms of cancer, however, including those of the lung, female breast, stomach or colon, are marked by much longer minimal latent periods of at least ten years from radiation exposure to death (BEIR, 1990).

## Registration Data

Nine population-based tumor registries in the continental United States (together with registries in Hawaii and Puerto Rico) are included in the Surveillance, Epidemiology and End Results (SEER) program supported by the National Cancer Institute. Several of the SEER registries cover only populous urban areas, places where nuclear facilities are

not built. Three of the registries, however, cover entire states: Connecticut (Haddam Neck and Millstone power stations), Iowa (Duane Arnold and Fort Calhoun) and New Jersey (Oyster Creek and Salem nuclear power stations). All of the SEER registries were fully in operation by 1973 except the Seattle-Puget Sound registry, which was in full operation by 1974, the Atlanta registry, by 1975, and the New Jersey registry, which became part of the SEER program in 1983. Registrations in New Jersey in the early years of its inclusion in SEER were incomplete and hence those data have not been used in this report. Although there were other cancer registries in the United States besides the SEER registries, the virtue of SEER is that essentially complete coverage is provided for the populations included, so that registration can be assumed to be as complete in control areas as in study areas.

Since thyroid cancer can be induced by radiation but is seldom fatal, the disease cannot be ascertained effectively through mortality reports. Similarly, cancer of the female breast often has a favorable prognosis, and even when it does cause death, the fatal outcome may be delayed for many years. Therapy for childhood leukemia has improved remarkably in recent years and deaths have been greatly reduced in number. Although there is great potential value in cancer registration (incidence) data, such data of good quality, covering a suitable span of years, were available for only the four facilities mentioned above, in relation to five counties: Middlesex and New London Counties (Connecticut) and Lynn, Benton and Harrison Counties (Iowa).

## STUDY COUNTIES

Mortality data were available for the years 1950 to 1984 inclusive. Since the radiation-inducible cancer with the shortest latency (time from exposure to onset of overt disease) is leukemia, which has at least a two-year latency (NIH, 1985), leukemias that may have resulted from exposures in 1982 or later cannot be identified in these data. Therefore, the set of facilities to be studied at this time is limited to those that were in operation at some time prior to 1982. Those facilities and the counties in which they are situated are shown in Appendix Table 2. The 62 facilities include 52 commercial nuclear electricity-generating plants, 9 facilities operated by contractors for the Department of Energy and its predecessor agencies, and one former commercial fuel reprocessing plant.

The 62 facilities are situated in 64 counties (the Idaho National Engineering Laboratory and the Oak Ridge National Laboratory each have individual plants in two counties). Although there were more than 80 commercial power reactors in operation before 1982, some plants have two or three reactors; thus there are fewer sites than there are reactors. It often happens, however, that a nuclear facility is located on or near the boundary between counties. In such cases, adjacent counties can be considered to be as much "at risk" as the county in which the facility is actually situated. Such an "adjacent county" was considered for inclusion as a "study county" only if it constitutes at least 20 percent of the area within a ten mile radius of the facility. The 50 counties that are included as study counties are shown in Appendix Table 3. Seven counties qualify with respect to two facilities and are included in both Appendix Tables 2 and 3 (Franklin, MA; York, PA; Manitowoc, WI; and Kewaunee, WI) or appear twice in Appendix Table 3 (Boulder, CO; Butler, OH; and Lancaster, PA). There are, therefore, just 107 different study counties included. Since the Point Beach and Kewaunee power plants are located in adjacent counties, for these purposes they are treated as a single installation named "Point Beach/Kewaunee"; therefore, data for the 62 facilities are presented under the headings of 61 study areas.

## CONTROL COUNTIES

Three control, or comparison, counties were identified for each study county (Appendix Table 4). Although an attempt was made to choose a different control set for each study county, this was not always possible; 292 different control counties are included in the study. To the extent feasible, control counties were chosen that are not too distant from the study county in question, usually from the same state but in a few instances from an adjacent state. As listed in Appendix Table 4, if a control county comes from an adjoining state, that state is shown explicitly. Control counties were matched to study counties on the basis of several characteristics for which data were available on a county basis: percentages in the population over age 25 that are white, black, American Indian, Hispanic, urban, rural farm, employed in manufacturing, and high school graduates; mean family income, net migration rate, infant death rate and population. Data for the matching exercise were for the year 1979, except for population which was for 1980. The relative

importance of each factor was calculated by use of a linear regression analysis, using the male lung cancer death rate in 1979 as a criterion. Lung cancer was chosen because it is sensitive to life style variations, especially smoking and exposure to industrial pollutants. It must be emphasized that control counties were not matched to study counties on the basis of lung cancer death rates; only the relative importance of the matching factors was determined by regression analysis based on all counties in the United States (as described below). The large differences among cancer death rates in different geographic areas are not completely understood and cannot, therefore, be accounted for using routinely available population statistics. For example, data on smoking, dietary factors (sometimes related to religion), or specific ethnic background were not available in the detail needed. Because the distributions of such factors tend to vary over broad geographic areas (e.g., ethnicity in the Southwest as contrasted with the Northeast, or religion-associated dietary factors in Utah and adjoining states) control counties were chosen from the same geographic region (usually from the same state) as the study counties in an attempt to control for such factors.

The continental United States was divided into six regions -- Northeast, Southeast, North Central, South Central, Mountain and Far West -- and regression analyses were performed separately within each region. After the regression coefficients were calculated, for each study county an index of similitude to that county was calculated for every other county in the region by summing the absolute values of the differences in the county characteristics multiplied by the corresponding regression coefficients. The candidate control counties were then listed in order of decreasing similitude, and from among the most similar, three control counties were selected based on geographic propinquity.

Figure 1 shows all of the study and control counties included. Counties with DOE facilities and their controls appear in Figure 2, and the corresponding counties with commercial nuclear electricity-generating facilities are shown in Figure 3.

Although data are shown only for certain age groups (under 10, 10-19, 20-39, 40-59, 60+, and all ages combined), calculations of expected numbers of deaths were based not only upon sex and race but upon individual calendar years and specific five-year age groups.

# NUCLEAR INSTALLATIONS, COMMERCIAL AND DOE

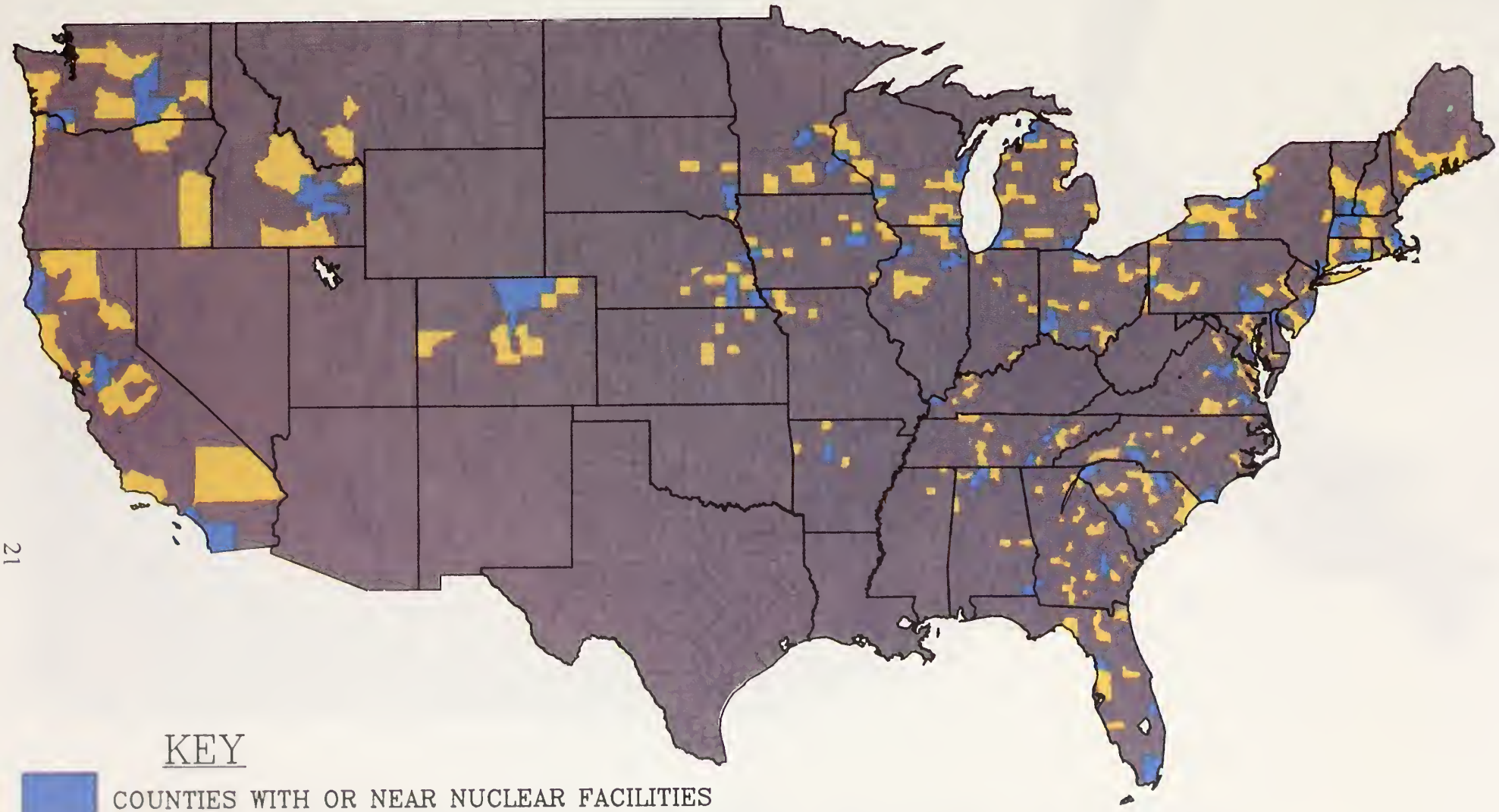



FIGURE 1

# DEPARTMENT OF ENERGY NUCLEAR FACILITIES

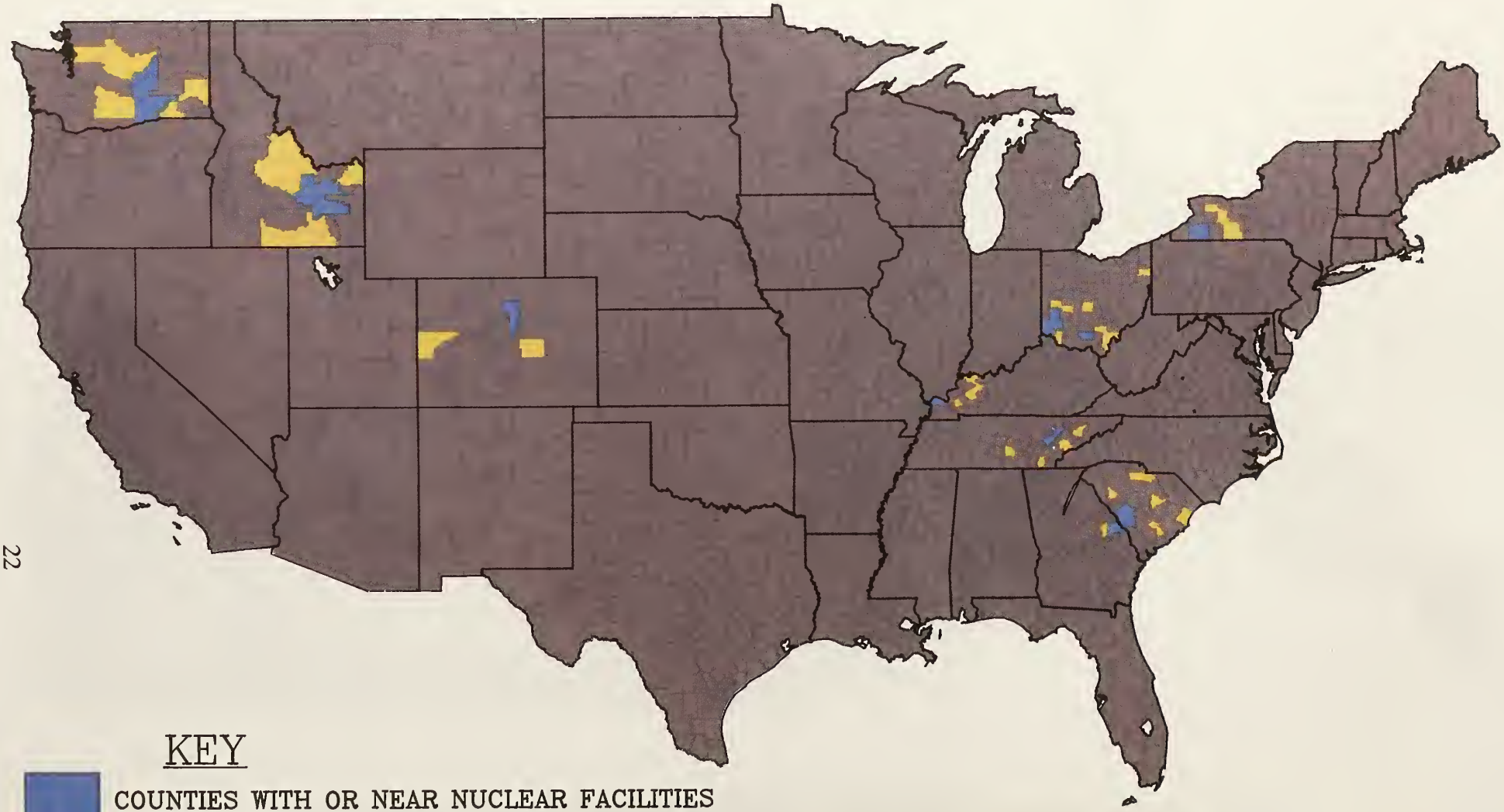
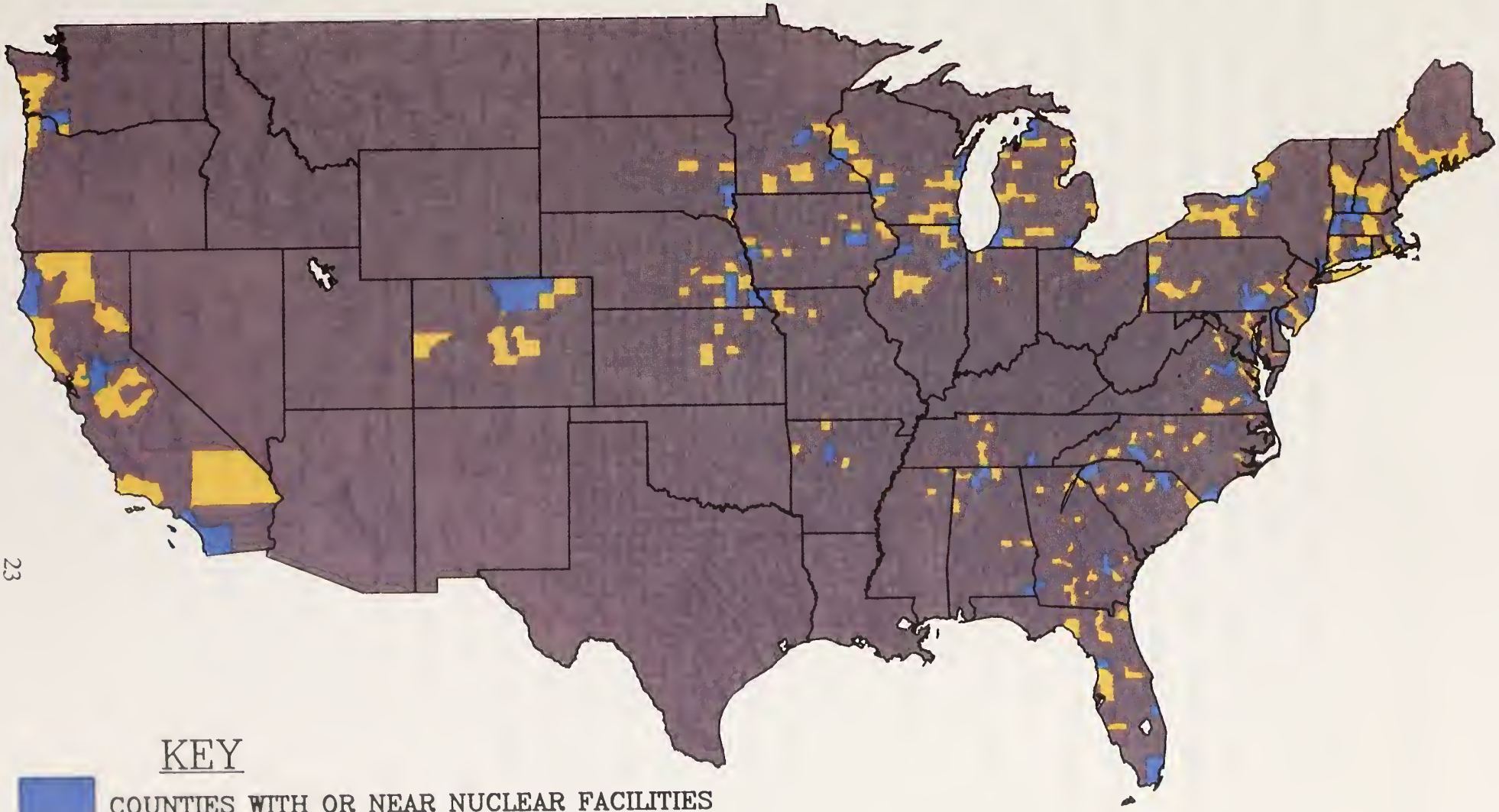



FIGURE 2

# COMMERCIAL NUCLEAR POWER PLANTS

## STARTUP 1957-81



KEY

COUNTIES WITH OR NEAR NUCLEAR FACILITIES

CONTROL COUNTIES

ALL OTHER COUNTIES

FIGURE 3

## FORM OF ANALYSIS

### Individual Facilities

When there was more than one study county relative to a particular facility, all such study counties and, similarly, their controls, were summed to provide the basis for an overall comparison for the facility. Analyses of cancer experience during the 35-year study period (1950-84) were then performed for the time periods before and after the point in time when the facility first went into service. These time periods were further analyzed in sequential 5-year units. For each facility, a base period was defined as the 5-year period in whose last year the facility started operations (or fewer years, if startup was prior to 1954). For certain DOE facilities that started prior to 1950, the base period was defined as 1950-54. Except for these DOE facilities, no excess cancers attributable to emissions from the facility could have occurred during the base or earlier periods. For facilities that started operations in 1950 or later, the earliest excess leukemia deaths could have occurred during the first period after the base period. Other forms of radiation-induced cancer, however, would take longer to appear and to cause death. The second period after the base period, therefore, which is at least five years after startup, is the earliest period during which excesses might be seen for cancers other than leukemia that could have been induced by plant emissions. If it is assumed that after the plant startup there were occasional or regularly occurring emissions, then, as time passed, the risk of death from induced cancer, if present, would presumably have increased, because of increasing cumulative exposures and also because it necessarily takes time after a cancer is initiated for it, first, to grow to a point where it is recognizable and, then, to cause death.

For each age group, time period and cause of death studied, the "expected" number of deaths was calculated for each county (both study and control counties). In each year the U.S. death rates were multiplied by the estimated population of the county, separately by 5-year age group, sex and race (white, non-white). The values for the two racial groups and the two sexes were then summed. The annual values were then summed for the time period. This procedure produced expected values based on U.S. experience, which provide one basis for judging whether a given county did or did not have unusually high or low cancer death rates. However, because such rates vary with urbanization and many other

factors, these comparisons were subsidiary to comparisons with corresponding data for the matched control counties.

The ratio of the actual number of deaths to the number expected at U.S. rates is the standardized mortality ratio, or SMR. Similarly, the ratio of the number of cancers registered to the number expected at overall SEER rates is the standardized registration ratio, or SRR. After calculation of SMRs (and SRRs when possible) for each county and facility for each cancer under study, the SMRs or SRRs for the study and control counties were compared. Volume 2 shows for each facility the actual number of deaths for each cause and age group, and the corresponding SMR. Shown also are the corresponding relative risks (RRs). The RRs for the individual facilities were calculated as the ratio of the SMRs (or SRRs). That is, denoting the

SMR in the Study area after startup : $SMR_{sa}$
SMR in the Control area after startup : $SMR_{ca}$
SMR in the Study area before startup : $SMR_{sb}$
SMR in the Control area before startup : $SMR_{cb}$

Then,

RR (Study vs. Control, After) = $SMR_{sa} \div SMR_{ca}$
RR (Study vs. Control, Before) = $SMR_{sb} \div SMR_{cb}$
RR (Study, After vs. Before) = $SMR_{sa} \div SMR_{sb}$
RR (Control, After vs. Before) = $SMR_{ca} \div SMR_{cb}$

RRs were not calculated in those instances where the data were considered to be too sparse: if the number of deaths in the numerator or the denominator was less than 3, or if their sum was less than 10.

The magnitude of the difference between each RR and unity was assessed by calculation of the probability that a difference of that magnitude, or larger, might arise by chance. For example, if $OBS_s$ and $OBS_c$ are the numbers of deaths from a particular cancer in the study and control counties, and if $EXP_s$ and $EXP_c$ are the expected values at concurrent U.S. rates, then $SMR_s = OBS_s \div EXP_s$, and similarly for the controls. The test whether the relative risk, RR (the ratio of the SMRs), differs from 1.00 is performed

by examining the distribution of $OBS_s$, which is treated as a binomial variate with parameters $n = [OBS_s + OBS_c]$ and $p = [EXP_s \div (EXP_s + EXP_c)]$. Tests were two-tailed except where explicitly noted otherwise.

Although the result of any particular test is reliable in the sense that the mathematical requirements for the test are satisfied, since thousands of such tests have been done, the results must be interpreted with some caution. There are, for example, in Volume 2, around 6000 different tests of the RR comparing the study and control areas after startup. About 300 of the tests can be expected to be "significant" at the $P \leq 0.05$ level simply as a result of random sampling variation, i.e., chance alone.

In addition to the problems in interpretation that result from multiple tests, the test results are affected by so-called "demographic variation". The matching of control to study counties could not be perfect and, consequently, the study and control counties differ as a result of differences in occupations and other demographic and lifestyle factors that are correlated with cancer rates. Moreover, in the period 1950-1969, when annual populations were estimated by linear interpolation in decennial census counts, the calculated "expected deaths" for some individual age groups may be inaccurate in years marked by extensive population movements. Although the tests are designed to detect differences that resulted from effects attributable to the nuclear facilities, they detect <u>all</u> differences, whether relevant or otherwise, that result from variations between the populations of the study and control counties.

It should be noted that the "after vs. before" RRs, whether for the study counties or the controls, are subject to bias that can result from varying rates of change in different counties in the occurrence of various forms of cancer, or in diagnostic practice, over the 35 year period for which data are presented. In particular, the SMR for any area will be increased or decreased if changes in the frequency of diagnosis of a particular form of cancer, or of all cancers, are different in that area from the national experience over time. Since the epidemiological characteristics of a county can change considerably in 35 years, the ratio of "SMR After" to "SMR Before", that is, the relative risk, can be affected by such change. Thus, the most appropriate comparison that minimizes to the extent possible these biases in changing disease and death coding patterns over time is the ratio of "SMR After" for the study area to "SMR After" for the control area.

The standardized mortality ratio is based on so-called "indirect age standardization" (Breslow and Day, 1987). In addition to certain favorable statistical properties, it has the further advantage that it can always be calculated. The "direct" method of age standardization cannot be employed if the data base is very sparse, as was the case here where for certain particular counties, calendar years, five-year age groups and specific types of cancer, there were no deaths and a very small exposure base. Since all calculations for this analysis were performed within six age groups, it was considered that there was little opportunity for bias of comparisons by differences in age distributions. This assumption was tested by calculation of directly standardized rates for the "All Facilities" tables. It was verified that, within age groups, the age distributions were so similar that RRs were affected only trivially, by at most 1.5% and usually less than 1%.

## Combinations of Facilities

Tables were also prepared for certain combinations of facilities, arranged similarly to the tables for individual facilities that are contained in Volume 2. To calculate relative risks for the combined data for a group of facilities (e.g., all electricity-generating plants), and to determine whether the combined RRs depart significantly from unity, a somewhat different approach was needed. The method used is an adaptation of the Mantel-Haenszel procedure for obtaining a valid test and an estimate of the overall RR for stratified data (Breslow and Day, 1987).[2]

Each study area and its associated control area constitute one stratum. Denote the observed deaths (for a particular cause) in the study and control area, and their sum, in the $i^{th.}$ stratum as $D_{s|i}$, $D_{c|i}$ and $D_{+|i}$, and the corresponding expected values as $E_{s|i}$ and so forth. Then

$$O_{s|T} = \text{Observed (Study)} = \Sigma_i D_{s|i}$$
$$E_{s|T} = \text{Expected (Study)} = \Sigma_i E_{s|i} \quad \text{and}$$
$$SMR_T = O_{s|T} \div E_{s|T}$$

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[2] We thank Professor Donald Pierce, who suggested this approach.

and the test of significance of the difference between the two groups is obtained by calculating a (approximately) normal deviate:

$$Z = \Sigma_i[D_{s|i} - D_{+|i}{}^*E_{s|i}/E_{+|i}] \div \text{SQRT}\ \{\Sigma_i[D_{+|i}{}^*E_{s|i}{}^*E_{c|i}/E_{+|i}{}^2]\}$$

while the relative risk is calculated as:

$$RR = \Sigma_i[D_{s|i}{}^*E_{c|i}/E_{+|i}] \div \Sigma_i[D_{c|i}{}^*E_{s|i}/E_{+|i}]$$

Data considered to be too sparse to support the calculation of RRs for individual facilities were not included in the sums used in the calculation of Z and RR for the combined facilities.

The effect of imperfect matching of study and control counties, discussed earlier, tends to inflate the absolute magnitude of Z. The procedure assumes that the matching process has eliminated all variation between the study and control counties in each stratum. Some residual variation, however, results from unmatched demographic factors and, consequently, the statistical significance of tests based on Z in the summary tables will be exaggerated.

If the numerator and denominator of RR are called N and D, then a little algebra shows that the numerator of Z is simply N - D, so that Z = 0 implies RR = 1.00 and conversely. It should be noted that the estimate of the overall RR can be written as a weighted average of the individual facility RRs and, in general, is not identical with the RR that would be calculated from the simple sums of the numbers of observed and expected deaths.

The British studies have found excesses of childhood leukemia, chiefly lymphoid leukemia, particularly in relation to the Sellafield and Dounreay reprocessing plants (Black, 1984; COMARE, 1986, 1988; Darby and Doll, 1987; Gardner et al., 1987a). The emissions and effluents from a reprocessing plant are different from those from a nuclear electric power installation, and if either should affect the health of nearby populations, the mechanisms cannot be assumed to be identical. It is desirable, therefore, to examine results for electric power reactors separately from those for other nuclear installations.

Even if the risks from the operation of particular plants are so small as not to be individually detectable, it is possible that by adding together the data from different plants, effects too small to be visible with respect to individual facilities might, nevertheless, be identified.

In accordance with this strategy, the data are shown for several groupings of plants:

| | |
|---|---|
| Table 1: | All Facilities Combined. |
| Table 1-A: | Department of Energy Facilities. |
| Table 1-B,C,D: | All Electric Utilities |
| Table 1-B: | Electric Utilities, Startup Before 1970 |
| Table 1-C: | Electric Utilities, Startup 1970-1974 |
| Table 1-D: | Electric Utilities, Startup 1975-1981 |

More detailed tabulations of individual study areas can be found in Volumes 2 and 3 of this report. Volume 2 consists of SMR and RR computations of cancer occurrence before and after startup for each individual study area and corresponding control area, by age at death groupings. Volume 3 contains SMR computations of cancer occurrence by 5-year calendar-time intervals from 1950 through 1984 for each individual study area, also by age at death groupings. Both volumes tabulate the observed number of cancer deaths. Cancer incidence data and SRR computations are presented when available.

## RESULTS

### ALL FACILITIES COMBINED

Summary Table 1, found in the back of this Volume, summarizes the data for all 61 study areas. The left-hand page shows, for each of the 16 cancer classes, the actual numbers of deaths and the corresponding SMRs (ratios of observed to expected numbers) in each age group in the study and control areas, before and after startup of the plants.

The right-hand page of Table 1 shows, for each cancer, four RRs: for the study area vs. the control area, before startup and after; and for each of the study and control areas, the RR comparing mortality after startup vs. before. Tests (two-tailed) of the statistical significance of the departure of each RR from unity are shown by asterisks appended to the RRs. Tests were not performed if the RR fell between 0.98 and 1.02, since the interpretation of "significance" for values so close to 1.00 has little meaning.

The primary comparisons are of study vs. control areas (sets of counties) after startup but there are additional comparisons: whether the RRs in the study or control counties themselves changed significantly from before to after startup, and whether the study and control counties differed before startup. If the latter is true, the comparability of the controls would be questionable. Note that since the tests are all two-tailed, they show the RRs to be sometimes significantly higher than 1.00, and sometimes lower.

Among children under age 10, the RR for leukemia comparing the study with the control areas after startup was 1.03, while the RR that compares the study area after startup with itself before startup was only 0.93; neither of these values was significantly different from 1.00. The RR for leukemia for study vs. control areas before startup, however, was 1.08 and significantly exceeded unity. Other RRs that were significantly different from unity for children under 10 included those for trachea, bronchus and lung (TBL) cancer (2.24, study vs. control, after startup) and that for all cancer except leukemia before startup, which was low (0.94, study vs. control). The RR of 2.24 for TBL cancer after startup is so large, in part, because of an abnormally low SMR (0.61) in the control area after startup; this was significantly lower than the SMR in the same area before startup (RR, 0.40). These results imply that the attempt to match the control to the study counties was not entirely successful with respect to cancer mortality over the entire 35-year period being studied.

For deaths at ages 10-19, the RRs for leukemia did not differ significantly from 1.00. Two of the RRs comparing the study and control areas after startup, however, were significantly different from unity: high for digestive cancer (1.30) and low for Hodgkin's disease (0.69).

At ages 20-39 the RR (study vs. control, after startup) for cancer of bones and joints was significantly high (1.27). The corresponding RR (1.16) comparing the areas before startup was also greater than 1.00 but was not significantly high.

At ages 40-59 there were three RRs (study vs. control, after startup) that were significantly different from 1.00; two of them were low, for stomach and for brain and other CNS cancer, while that for female breast cancer was high, although only 1.03. The number of deaths in this age group, over the entire period either before or after startup, was sufficiently large (nearly 125,000 cancer deaths after startup in the study areas) so that a small increase in risk, e.g., 3% for female breast cancer, was statistically significant. There were also several RRs significantly different from 1.00 between the study and control areas before startup. Like those after startup, most were near 1.00 and achieved technical statistical "significance" only because of the very large numbers of deaths included.

Deaths from cancer at ages above 60 were very numerous -- hundreds of thousands each in the study and control areas, both before and after startup. There are, consequently, very many "highly significant" differences between study and control areas, before startup and after, and between before and after startup. Again, despite their statistical "significance" most of the RRs were near 1.00, and the differences do not appear to be meaningful.

Figure 4 displays the distributions of the RRs for leukemia mortality in children under age 10 in the individual facilities. The four panels in the figure show the comparisons of study vs. control before, and after, startup and also the comparisons of each area after startup with itself before. RRs based on fewer than 3 deaths in the numerator or denominator, or where there were fewer than 10 deaths in the numerator and denominator combined, are omitted from the figure; and there are no "before startup" data for facilities whose startup was before 1950 (e.g., Oak Ridge).

Although there were more areas with RR $\geq$ 1.00 after startup in the study areas, the excess was trivial (19 areas with RR $\geq$ 1.00 compared with 16 areas with RR $<$ 1.00). The

discrepancy was considerably larger before startup (35 areas with RR ≥ 1.00 and only 16 areas with RR < 1.00); this difference is highly significant. In the study area, comparing the data after startup with that before, 16 RRs were 1.00 or more and 16 were less than 1.00, while a similar comparison for the control areas showed 25 RRs ≥ 1.00 and 22 RRs < 1.00.

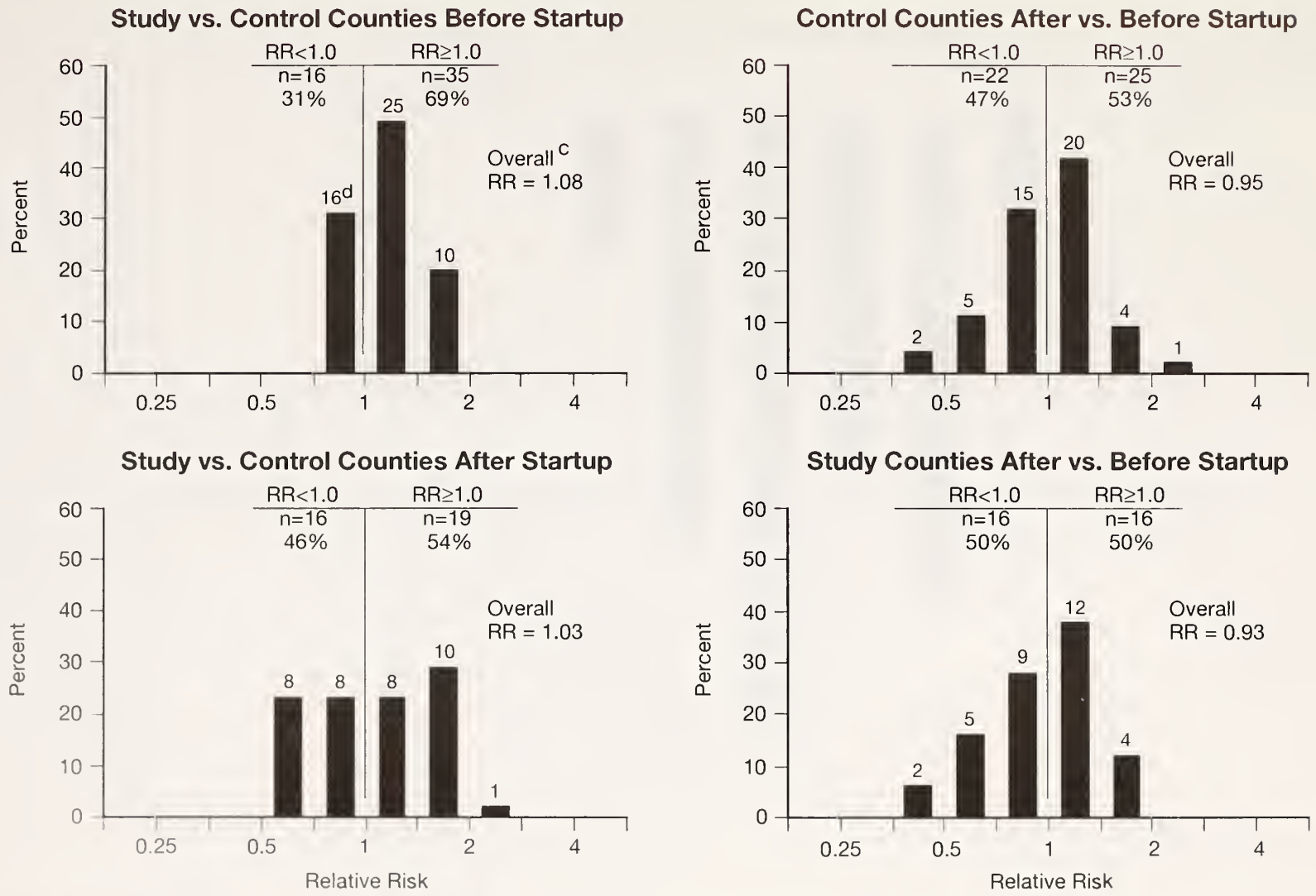
Changes in the RRs for childhood leukemia from before to after startup are shown in Figure 5. In 15 instances the ratio of the RRs increased, while in 17 it decreased.

Figure 6 shows the distributions of the leukemia RRs for all age groups; each RR pertains to a particular facility and age group. The overall RRs are shown also. For the study vs. control areas after startup there were 107 RRs of 1.00 or more, but 116 less than 1.00 and the overall RR was 0.98. Before startup there were 134 RRs larger and 114 smaller than 1.00 with an overall RR of 1.02. Comparing the data after startup vs. before, in the study areas there were 110 RRs larger than 1.00 and 98 smaller while in the control areas there were 151 RRs larger and 99 smaller; this last difference is statistically highly significant.

Figure 7 shows the data similarly, for all cancer except leukemia, for children under 10 years. When the study areas were compared with either the control areas after startup or themselves before startup, a little less than two-thirds of the facilities had RRs of 1.00 or more; the overall RRs were 0.99 (vs. control areas) and 1.05 (vs. themselves before startup). The before-startup comparisons and the after-to-before comparisons for the control areas both had a majority of RRs less than 1.00. The apparent excesses of RRs above 1.00 in the study areas are, however, not significant.

Figure 8 shows the distributions of RRs for all cancer except leukemia for all of the age groups in all of the facilities. All four of the distributions have a majority of the RRs of 1.00 or more, whatever the comparison, including study vs. control areas after startup or before, or either set of areas after startup compared with before. The largest discrepancy, however, is for the study areas, comparing the experience after startup of the associated facilities with that before (62% are 1.00 or more); this excess is significant. However, the overall RR is only 1.01, as is the overall RR for the comparison of the study with the control counties.

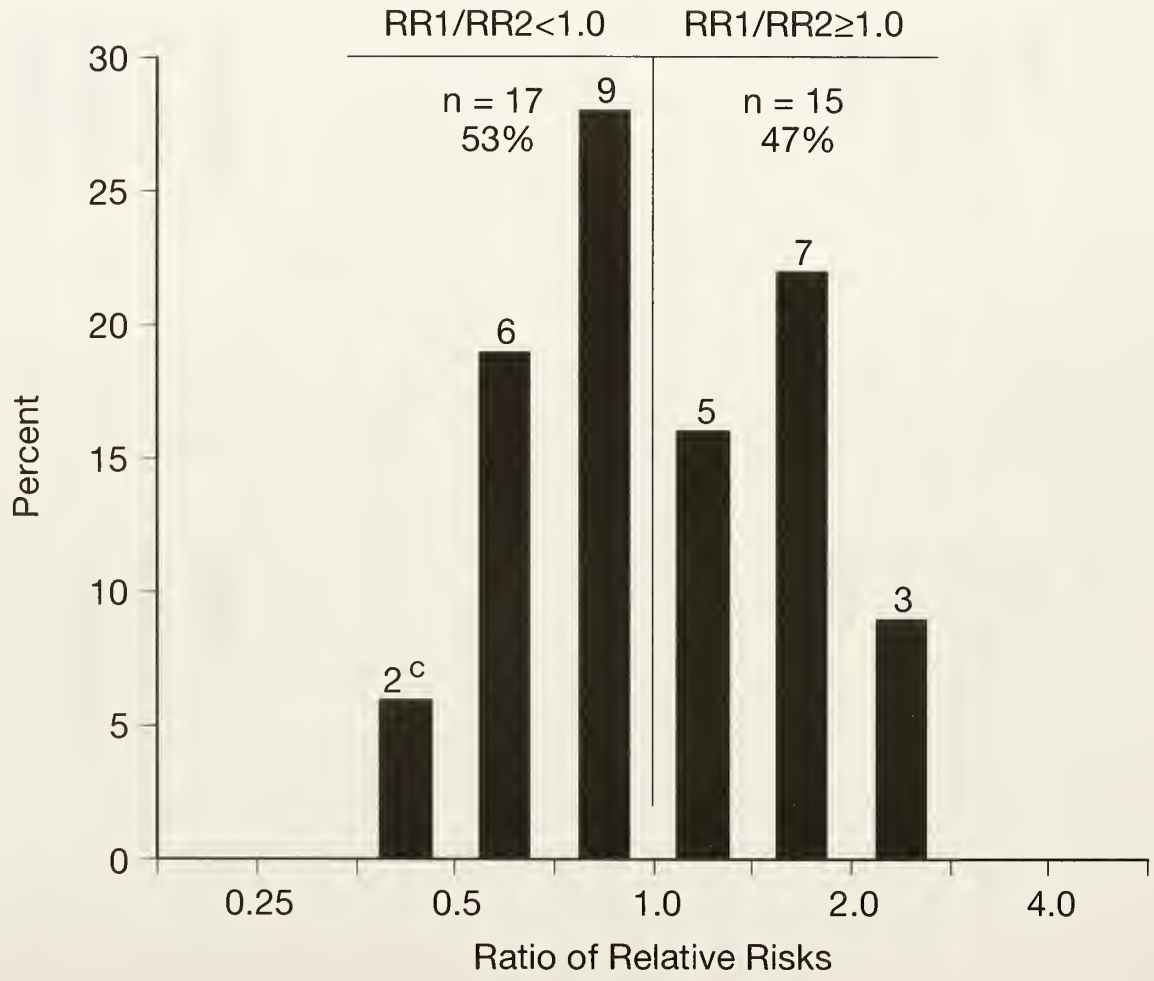
## Figure 4. Distribution of Relative Risks [a] of CHILDHOOD [b] LEUKEMIA for all Nuclear Facilities by Type of Comparison




a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented vary.
b Under age ten years.
c Weighted average relative risk, see text.
d Number of RR values in interval.

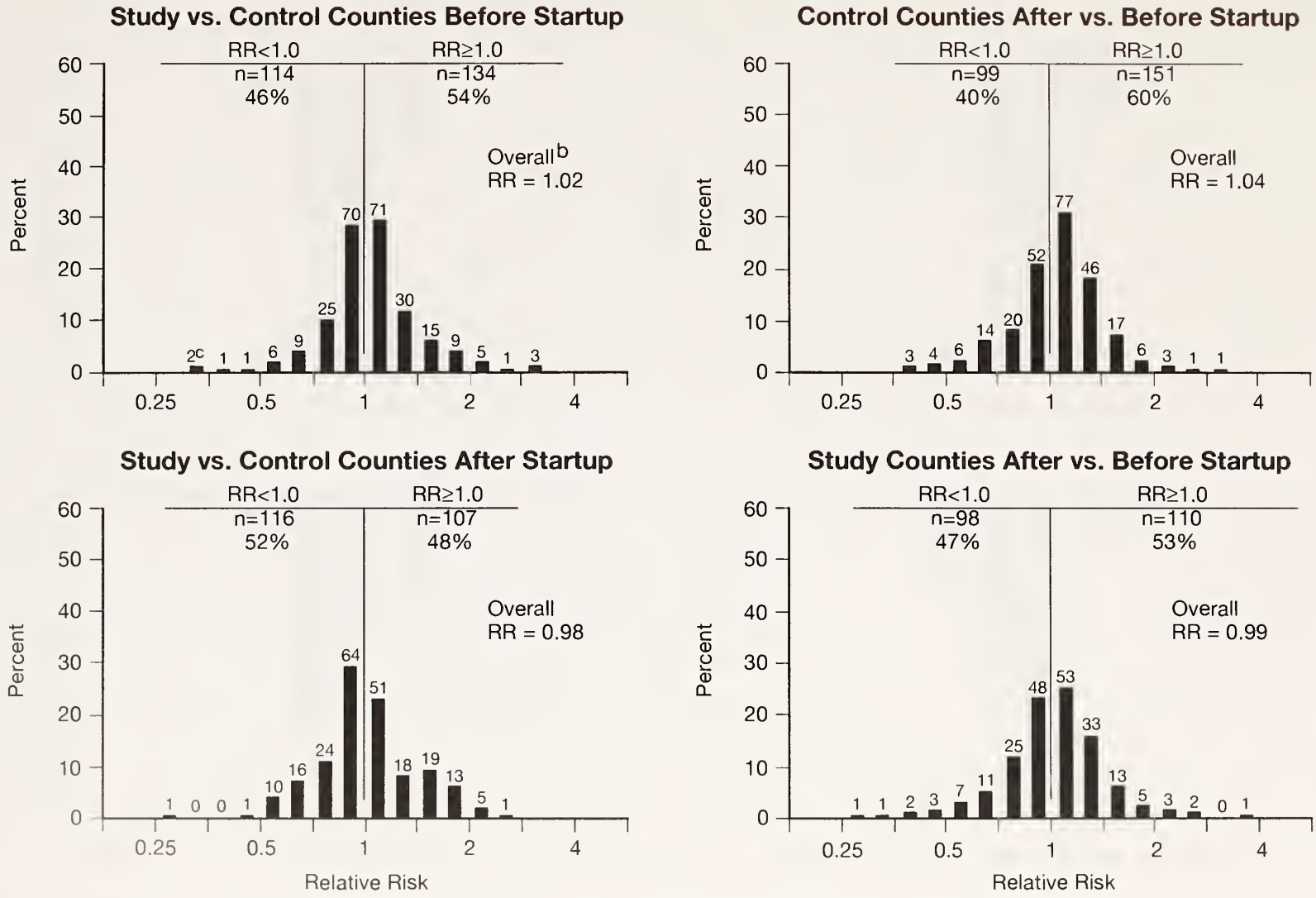
## Figure 5. Distribution of RATIOS of Relative Risks [a] of CHILDHOOD [b] LEUKEMIA

$$\frac{RR1}{RR2} = \frac{\text{Study vs. Control County After Startup}}{\text{Study vs. Control County Before Startup}}$$



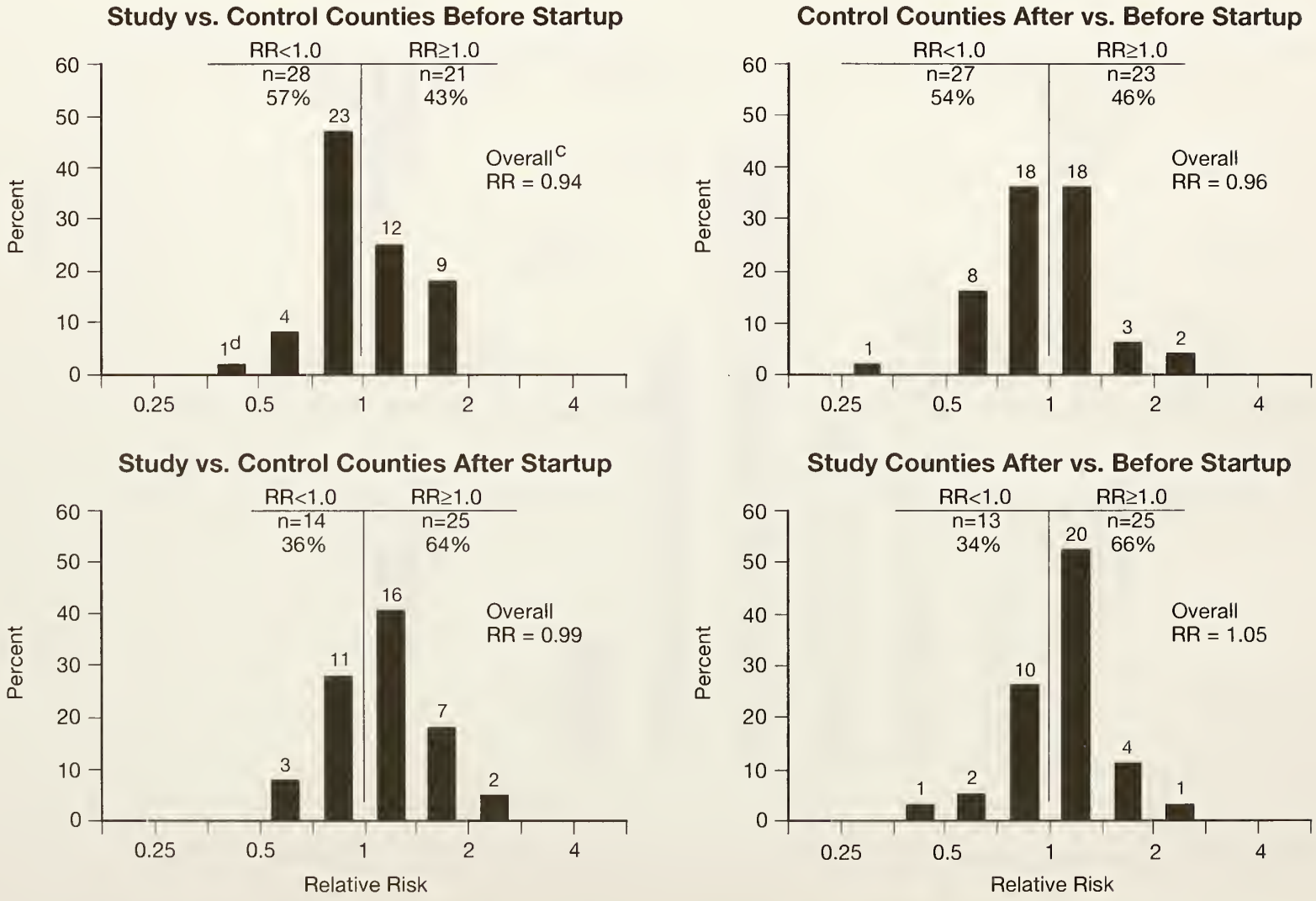

a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented do not sum to 61.
b Under age ten years.
c Number of values in interval.

**Figure 6. Distribution of Relative Risks[a] of LEUKEMIA, all Age Groups, for all Nuclear Facilities by Type of Comparison**



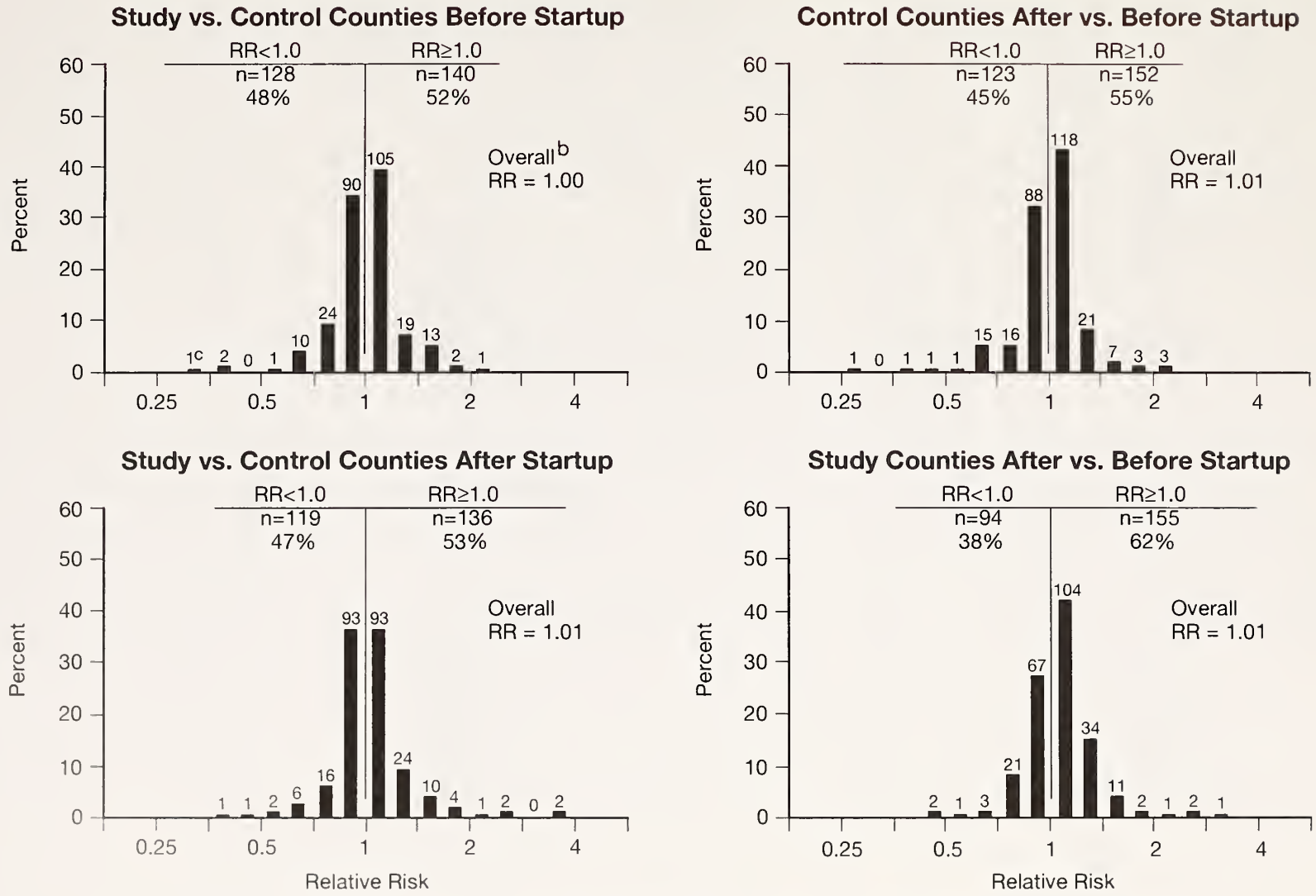

a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented do not sum to 305 (61 facilities x 5 age groups).
b Weighted average relative risk, see text.
c Number of RR values in interval.

## Figure 7. Distribution of Relative Risks [a] of CHILDHOOD [b] NON-LEUKEMIA CANCER for all Nuclear Facilities by Type of Comparison




a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented do not sum to 61.
b Under age ten years.
c Weighted average relative risk, see text.
d Number of RR values in interval.

# Figure 8. Distribution of Relative Risks[a] of NON-LEUKEMIA CANCER, all Age Groups, for all Nuclear Facilities by Type of Comparison




a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented do not sum to 305 (61 facilities x 5 age groups).

b Weighted average relative risk, see text.

c Number of RR values in interval.

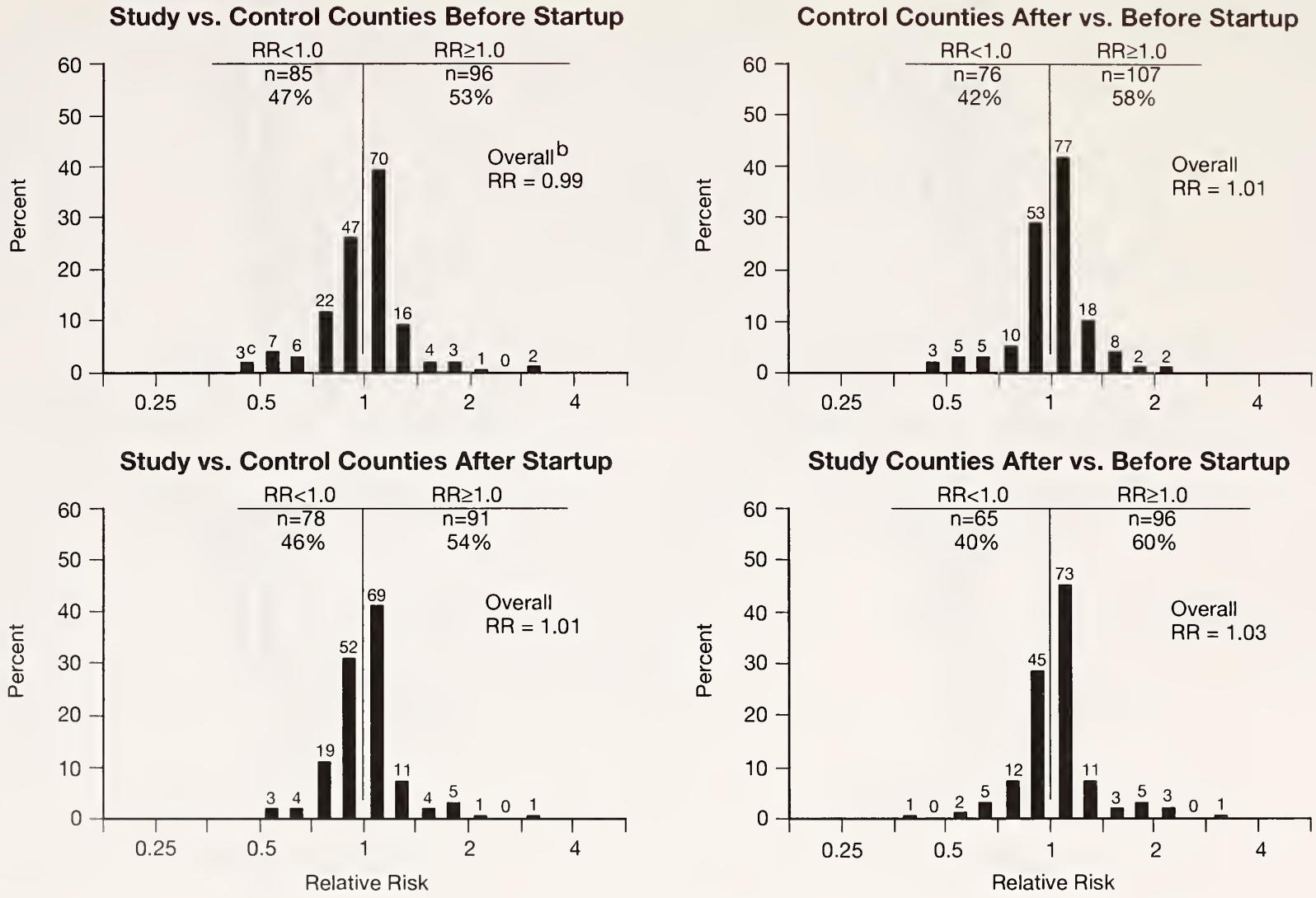
In short, three of the 16 distributions shown in Figures 4, 6, 7 and 8 are shifted significantly to the right, in the direction of RRs larger than 1.00. One is for leukemia in children below age 10, in the comparison of the study and control counties before startup; another is for leukemia in all age groups, comparing the control areas after startup with themselves before, and the third is for all cancer except leukemia for all age groups, comparing the study areas after with themselves before startup. The patterns do not point to any general excesses that might be associated with the nuclear installations, and display graphically the apparent randomness of these county mortality data.

Similar distributions of the RRs for all facilities and all age groups are shown for digestive cancers in Figure 9. In all four of the distributions the number of RRs larger than 1.0 exceeds the number that are smaller. The overall RRs, however, vary only between 0.99 and 1.03.

Figure 10 displays similar plots for lung cancer mortality. Again, no RRs are included that had fewer than three deaths in the numerator or the denominator, or that had fewer than ten deaths in the numerator and denominator combined. Recall that the "study vs. control after startup" is the most relevant comparison with regard to possible radiation effects. As is true for digestive cancer, for all comparisons, the RRs are shifted to the right. That is to say, for both the study and control counties, the RRs comparing risks after startup with those before exceed 1.00, and the RRs that compare the study with the control counties, both before startup and after, are also more frequently larger than smaller than 1.00. On the other hand, the great majority of the RRs are near 1.00, and the overall RRs are all between 0.98 and 1.01.

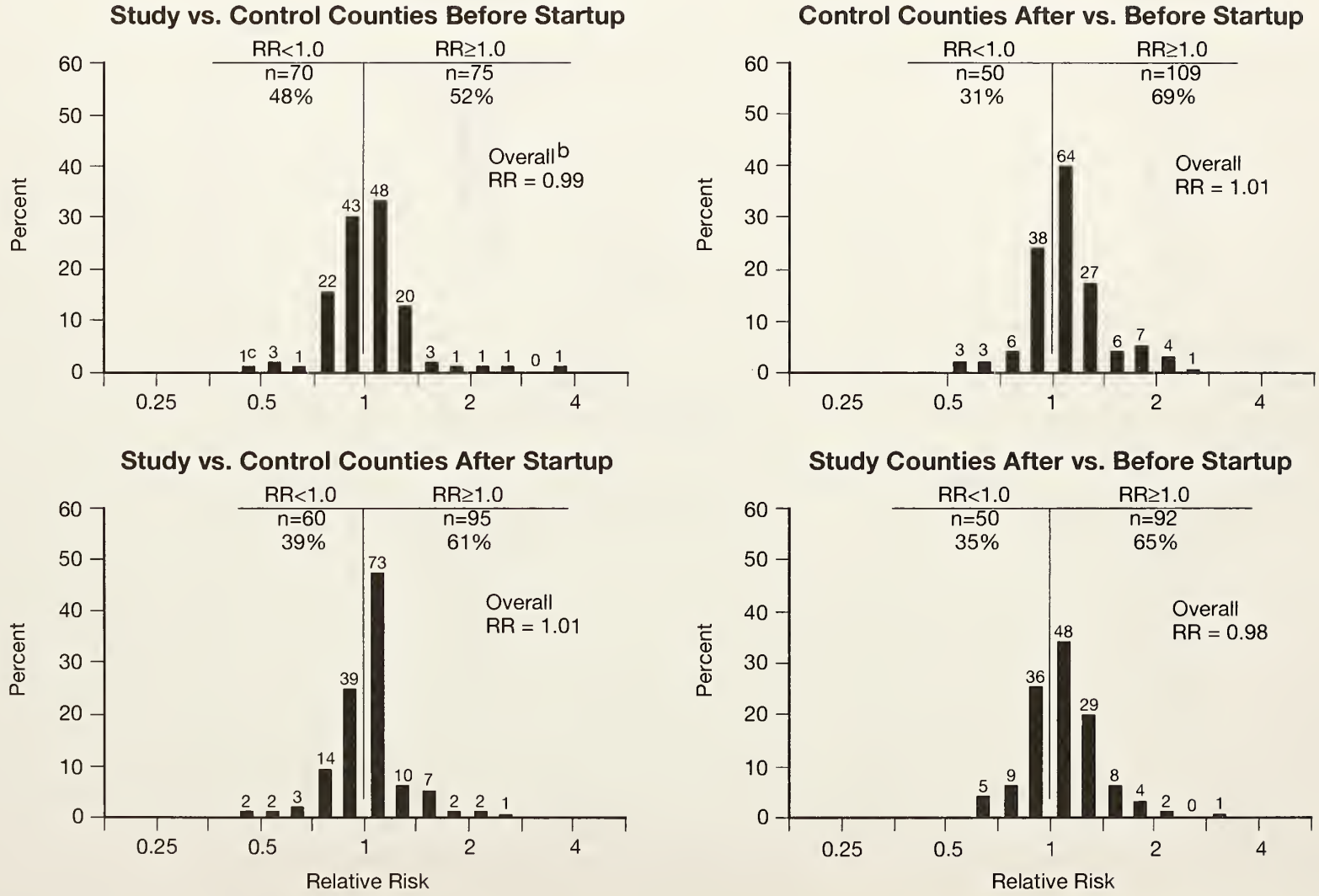
Figure 11 displays, similarly, the distributions of the RRs for female breast cancer. In all four panels, the number of RRs larger than 1.00 exceeds the number that are less, but the largest, and only statistically significant discrepancy is for the control counties, comparing risks before to those after startup; the overall RRs vary only between 1.01 and 1.03.

## Figure 9. Distribution of Relative Risks[a] of DIGESTIVE CANCER, all Age Groups, for all Nuclear Facilities by Type of Comparison



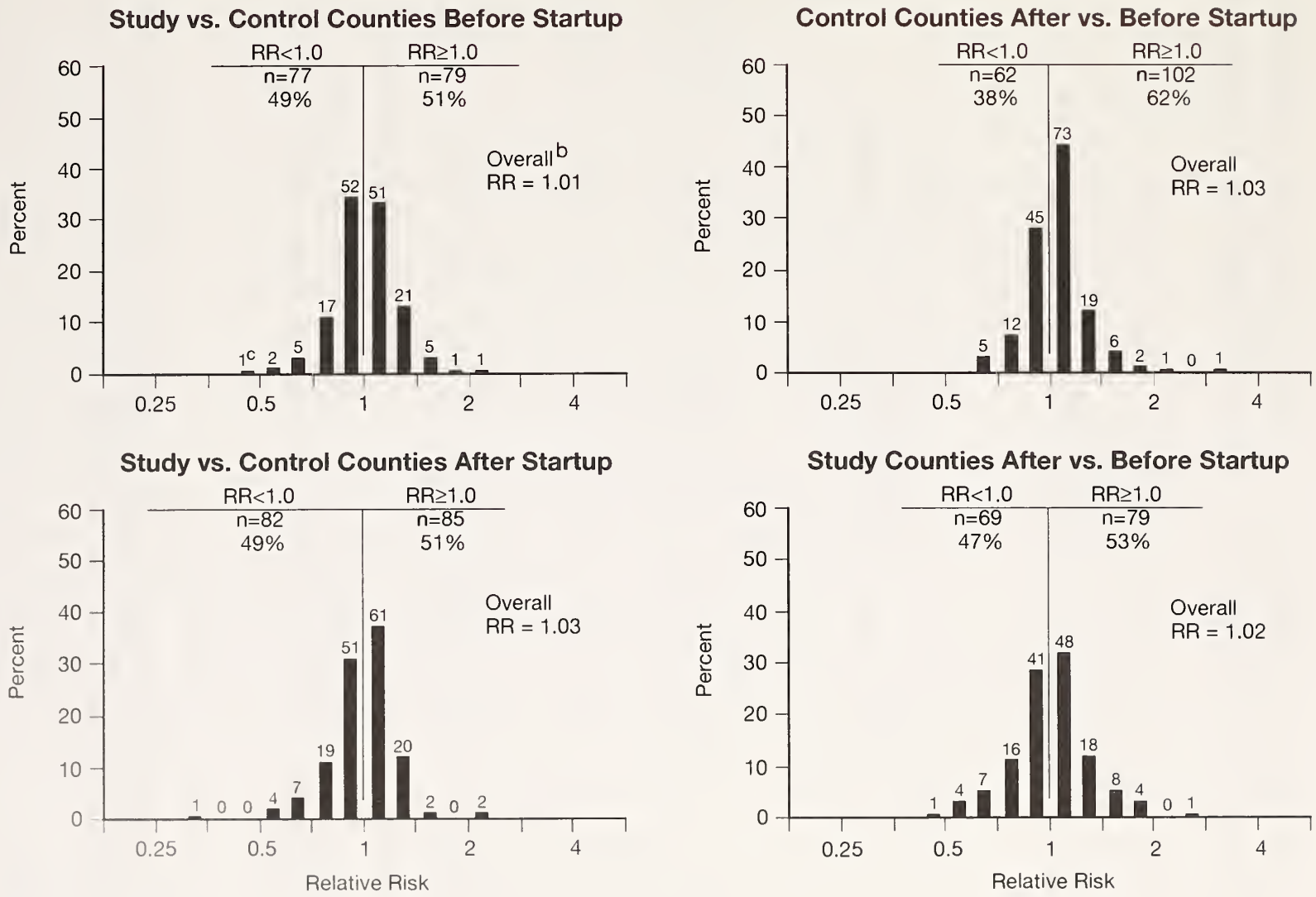

a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented do not sum to 305 (61 facilities x 5 age groups).
b Weighted average relative risk, see text.
c Number of RR values in interval.

## Figure 10. Distribution of Relative Risks[a] of LUNG CANCER, all Age Groups, for all Nuclear Facilities by Type of Comparison




a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented do not sum to 305 (61 facilities x 5 age groups).
b Weighted average relative risk, see text.
c Number of RR values in interval.

# Figure 11. Distribution of Relative Risks[a] of Female BREAST CANCER, all Age Groups, for all Nuclear Facilities by Type of Comparison




a RR values are included only if there are three or more deaths in both numerator and denominator and a total of ten in the numerator and denominator combined. Thus the numbers presented do not sum to 305 (61 facilities x 5 age groups).

b Weighted average relative risk, see text.

c Number of RR values in interval.

Text Tables 1 to 4 summarize the numbers of deaths, SMRs and RRs for death from leukemia and for all cancer except leukemia, for children under age 10 and for all ages.

Text Table 1 shows that for childhood leukemia mortality, for each group of facilities, whether electric utilities or Department of Energy facilities, the RRs comparing the study with the control counties were always smaller after startup than they were before startup.

Text Table 1
Mortality from Leukemia, Under Age 10, by Type of Facility

| Type of Facility | Before Startup | | | | | After Startup | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | | Study | | Control | | |
| | Obs. | SMR[a] | Obs. | SMR | RR[b] | Obs. | SMR[a] | Obs. | SMR | RR[b] |
| Department of Energy | 39 | 1.18 | 48 | 0.84 | 1.45 | 601 | 1.01 | 1009 | 0.96 | 1.06 |
| Electric Utilities | | | | | | | | | | |
| Before 1970 | 593 | 1.09 | 1035 | 1.05 | 1.03 | 534 | 1.03 | 993 | 1.00 | 1.00 |
| 1970-1974 | 996 | 1.06 | 2383 | 0.98 | 1.09* | 227 | 1.00 | 482 | 0.94 | 1.06 |
| 1975-1981 | 392 | 1.07 | 785 | 0.95 | 1.11 | 28 | 0.70 | 88 | 0.93 | 0.82 |
| TOTAL | 1981 | 1.07 | 4203 | 0.99 | 1.08* | 789 | 1.01 | 1563 | 0.98 | 1.01 |
| **All Facilities** | **2020** | **1.07** | **4251** | **0.99** | **1.08*** | **1390** | **1.01** | **2572** | **0.97** | **1.03** |

[a] Based on national mortality statistics.

[b] Comparison of study with control counties. The RR for combined facilities is obtained by a Mantel-Haenszel-type procedure and sometimes differs from the simple ratio of the SMRs.

*$p < 0.05$

Text Table 2 concerns leukemia mortality in all age groups, and similarly shows smaller RRs after startup than before. After startup, the RRs are, in fact, all a trifle smaller than 1.00.

Text Table 2
Mortality from Leukemia, All Ages, by Type of Facility

| Type of Facility | Before Startup | | | | | After Startup | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | | Study | | Control | | |
| | Obs. | SMR[a] | Obs. | SMR | RR[b] | Obs. | SMR[a] | Obs. | SMR | RR[b] |
| Department of Energy | 258 | 1.01 | 401 | 0.92 | 1.07 | 6077 | 1.00 | 11657 | 1.03 | 0.96* |
| Electric Utilities | | | | | | | | | | |
| Before 1970 | 4088 | 1.02 | 7235 | 0.99 | 1.05* | 8478 | 1.00 | 15474 | 1.01 | 0.99 |
| 1970-1974 | 8354 | 0.97 | 21172 | 0.97 | 1.00 | 5615 | 0.97 | 12823 | 1.00 | 0.98 |
| 1975-1981 | 3307 | 0.99 | 7163 | 0.94 | 1.04 | 1006 | 0.92 | 2620 | 0.95 | 0.98 |
| TOTAL | 15749 | 0.99 | 35570 | 0.97 | 1.02 | 15099 | 0.98 | 30917 | 1.00 | 0.99 |
| **All Facilities** | **16007** | **0.99** | **35971** | **0.97** | **1.02** | **21176** | **0.98** | **42574** | **1.01** | **0.98*** |

[a] Based on national mortality statistics.

[b] Comparison of study with control counties. The RR for combined facilities is obtained by a Mantel-Haenszel-type procedure and sometimes differs from the simple ratio of the SMRs.

*$p < 0.05$

Text Table 3 presents the summary data for mortality from cancer other than leukemia in children under 10. The RRs after startup are sometimes smaller and sometimes larger than those before startup. Interestingly, the largest RR (1.24 after startup) is for the later electric utilities, those that began operations in the period 1975 to 1981; since, for other cancer than leukemia, a minimum latent period of ten years from

exposure to death is generally accepted, there is little possibility that this large RR results from operation of those electricity-generating plants. In fact, as Text Table 3 shows, the SMR in the study counties is only 1.02; the RR is so large, not because risks were large in the study area, but because, for unknown reasons, mortality in the control areas was low -- the SMR was only 0.85.

Text Table 3
Mortality from All Cancer Except Leukemia,
Under Age 10, by Type of Facility

| Type of Facility | Before Startup | | | | | After Startup | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | | Study | | Control | | |
| | Obs. | SMR[a] | Obs. | SMR | RR[b] | Obs. | SMR[a] | Obs. | SMR | RR[b] |
| Department of Energy | 37 | 1.06 | 56 | 0.93 | 1.06 | 660 | 0.99 | 1233 | 1.05 | 0.95 |
| Electric Utilities | | | | | | | | | | |
| Before 1970 | 600 | 1.07 | 1038 | 1.02 | 0.99 | 654 | 1.07 | 1200 | 1.05 | 0.96 |
| 1970-1974 | 921 | 0.94 | 2600 | 1.03 | 0.89* | 340 | 1.07 | 687 | 0.97 | 1.07 |
| 1975-1981 | 411 | 1.01 | 929 | 1.03 | 0.99 | 63 | 1.02 | 123 | 0.85 | 1.24 |
| TOTAL | 1932 | 0.99 | 4567 | 1.03 | 0.94* | 1057 | 1.06 | 2010 | 1.01 | 1.01 |
| **All Facilities** | **1969** | **0.99** | **4623** | **1.03** | **0.94*** | **1717** | **1.03** | **3243** | **1.02** | **0.99** |

[a] Based on national mortality statistics.

[b] Comparison of study with control counties. The RR for combined facilities is obtained by a Mantel-Haenszel-type procedure and sometimes differs from the simple ratio of the SMRs.

*$p < 0.05$

Finally, Text Table 4 shows the data for all age groups, for all non-leukemia cancer. The RRs are all close to 1.00; the range after startup in the different groups was only from 0.98 to 1.04. Before startup, too, the RRs were close to unity and, combining all facilities, the RR after startup was 1.01.

Text Table 4
Mortality from All Cancer Except Leukemia,
All Ages, by Type of Facility

| Type of Facility | Before Startup | | | | | After Startup | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | | Study | | Control | | |
| | Obs. | SMR[a] | Obs. | SMR | RR[b] | Obs. | SMR[a] | Obs. | SMR | RR[b] |
| Department of Energy | 5780 | 1.04 | 8991 | 0.96 | 1.06* | 141635 | 1.06 | 247308 | 0.99 | 1.04* |
| Electric Utilities | | | | | | | | | | |
| Before 1970 | 79902 | 1.00 | 157745 | 1.06 | 1.00 | 197158 | 1.02 | 364675 | 1.05 | 1.01 |
| 1970-1974 | 179208 | 0.99 | 471890 | 1.02 | 0.98* | 139175 | 0.99 | 317206 | 1.02 | 0.98* |
| 1975-1981 | 69310 | 0.96 | 157884 | 0.96 | 1.02* | 26325 | 0.98 | 68785 | 1.01 | 0.99 |
| TOTAL | 328420 | 0.98 | 787519 | 1.01 | 0.99 | 362658 | 1.01 | 750666 | 1.04 | 0.99 |
| **All Facilities** | **334200** | **0.99** | **796510** | **1.01** | **1.00** | **504293** | **1.02** | **997974** | **1.02** | **1.01** |

[a] Based on national mortality statistics.

[b] Comparison of study with control counties. The RR for combined facilities is obtained by a Mantel-Haenszel-type procedure and sometimes differs from the simple ratio of the SMRs.

*$p < 0.05$

## A. Department of Energy Facilities

Included in the survey are nine plants operated by contractors for the Department of Energy. A tenth facility, the Nuclear Fuel Services plant, which was a commercial fuel reprocessing plant, is also included in the set. The ten facilities are:

1. Hanford Production Operations, Richland, Washington. Operations were begun in 1943. The facility reprocesses reactor fuel to recover plutonium and uranium. Other activities have included nuclear fuel fabrication and the operation of a number of reactors which produce nuclear materials. A developmental program involves use of a Liquid Metal Reactor.

2. Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee began operations in 1943. Oak Ridge is a multiprogram laboratory. Activities include, among others, isotope separation, transuranium element processing and, until 1985, production of enriched uranium by gaseous diffusion.

3. Mound Facility, Miamisburg, Ohio. This plant began operating in 1947. Among other activities, it is concerned with tritium technology, plutonium heat source development and isotope separation.

4. Idaho National Engineering Laboratory (INEL), near Idaho Falls, Idaho. INEL started operations in 1949. Among other activities, it reprocesses spent nuclear fuel, operates several test reactors, produces isotopes and operates a radioactive waste storage facility.

5. Paducah Gaseous Diffusion Plant, Ballard County, Kentucky started operations in 1950. It produces enriched uranium by gaseous diffusion.

6. Savannah River Facility, Aiken, South Carolina. Operations were begun in 1950 and include operation of reactors for the production of plutonium and tritium, nuclear fuel fabrication and reprocessing, and radioactive waste management.

7. Feed Materials Production Center, Fernald, Ohio. The facility began service in 1951. Operations include the processing of uranium metal and compounds and the production of billets from depleted uranium and from slightly enriched uranium.

8. Portsmouth Gaseous Diffusion Plant, Piketon, Ohio. This plant came into service in 1952. It produces enriched uranium by gaseous diffusion.

9. Rocky Flats Plant, Golden, Colorado. Rocky Flats began operations in 1953. This is a weapons plant that, among other activities, fabricates plutonium and uranium parts and recovers plutonium residues.

10. Nuclear Fuel Services, West Valley, New York. This was a private, commercially operated facility that reprocessed nuclear fuel. Operations began in 1966 and terminated in 1972.

Results for the combined study counties and their controls for the ten plants are shown in Table 1-A. Data for the ten facilities individually are given in Volume 2 in Tables 1-A.1 to 1-A.10 and in Volume 3 in Tables 2-A.1 to 2-A.10.

Table 1-A summarizes the data with respect to time before or after startup and shows a large number of significant differences for deaths at age 40-59, 60+, and for all ages combined.

For children below age 10, the RR comparing the study and control areas after startup for cancer of the trachea, bronchus and lung (TBL), which is extremely rare in children, was significantly larger than 1.00 (RR, 2.65). Among children 10-19, the RR for Hodgkin's disease was significantly low (0.56) while that for bone and joint cancer was high (1.34).

At ages 20-39 three of the RRs comparing the study and control areas after startup were significantly high: primary liver cancer (1.37), female breast cancer (1.15) and bone and joint cancer (1.37).

For ages 40-59, 60+ and all ages combined, there were many RRs that differed from unity, in a highly significant way; in most, but not all, instances the RRs were greater than 1.00. However, few of the RRs differ very much from 1.00; most are in the range from 0.90 to 1.10 and have little potential meaning. The statistical "significance" is a consequence of the very large number of deaths -- nearly a half-million altogether.

## B, C, D. All Electric Utilities

The number of deaths from 1950 through 1984 that occurred in the electric utility study and control counties is very large: in the study counties after the startup of the respective facilities, more than 380,000 deaths occurred from all forms of cancer, at all ages (Table 1-B,C,D). There were nearly as many deaths before startup and there were more than twice as many deaths in the control areas. These numbers are so large that even quite small differences from 1.00 in the RRs sometimes achieve statistical significance.

Table 1-B,C,D shows, for deaths under the age of 10, not a single significantly elevated (or decreased) RR, for any disease, between the study and control areas after startup. Before startup, however, the RR for leukemia was significantly large (1.08) while that for all cancer except leukemia was small (0.94). At ages 10-19 there were no significantly increased RRs for any form of cancer; but there was a significantly decreased RR for leukemia after startup (0.88).

In the age group 20-39 years only one RR, comparing the study and control areas after startup was significantly elevated: for bone and joint cancer (RR, 1.21). A significantly elevated RR of 1.10 for leukemia in the controls showed that there was an increase in the control areas after the plants' startup.

At ages 40-59, there were tens of thousands of cancer deaths and several very highly significant ($P < 0.001$) RRs, but none of them for the study vs. control area comparison after startup. Just one such RR was significantly decreased: for brain and other CNS cancer (0.94). Other highly significant RRs compared the two areas before startup, and compared each set of areas before and after. Most of these RRs were not very different from unity, but the numbers of deaths were large enough to give them statistical stability.

In the oldest persons, those who died at age 60+, for two kinds of cancer there were significantly elevated RRs: for "other" lymphoma (1.05) and for colorectal cancer (1.02). There were many RRs that were very highly ($P < 0.001$) significant, both high and low, comparing the areas before startup and, for Control, before vs. after. The mortality rates increased from before to after startup in the study areas for all cancer except leukemia (RR, 1.02) and for several specific kinds of cancer.

## B. Startup Before 1970

Fifteen commercial electricity-generating plants came into service prior to 1970 (Text Table 5); the earliest (1957) was the Shippingport Atomic Power Station, rated at 60 megawatts net electricity-generating capacity (MWe), in Beaver County, Pennsylvania.

Text Table 5
Electricity-generating Plants in Service Before 1970

| | Initially Critical* | Power Rating (MWe)** Initially | Units Added | (and Year) |
|---|---|---|---|---|
| 1. Shippingport/ | 1957 | 60 | 90,60 | ('65,'77) |
| Beaver Valley | 1976 | 810 | | |
| 2. Dresden 1 | 1959 | 200 | 772, 773 | ('70,'71) |
| 3. Yankee Rowe | 1960 | 167 | | |
| 4. Big Rock Point | 1962 | 69 | | |
| 5. Hallam | 1962 | 75 | | |
| 6. Indian Point 1 | 1962 | 265 | 849, 965 | ('73,'76) |
| 7. Fermi 1 | 1963 | 61 | 1093 | ('85) |
| 8. Humboldt Bay | 1963 | 65 | | |
| 9. Pathfinder | 1964 | 58 | | |
| 10. Haddam Neck | 1967 | 569 | | |
| 11. La Crosse | 1967 | 48 | | |
| 12. San Onofre 1 | 1967 | 436 | 1070, 1080 | ('82,'83) |
| 13. Ginna | 1969 | 470 | | |
| 14. Nine Mile Point | 1969 | 610 | | |
| 15. Oyster Creek | 1969 | 620 | | |

* Date of first sustained chain reaction.

** Reactor power is measured in several ways: Design rating, gross power output, net output etc. The numbers shown here reflect the approximate capacity of the reactors.

Source: DOE (1987).

The Shippingport reactor was shut down permanently in 1982, but Beaver Valley #1, rated at 810 MWe, was put into service in 1976. Many other early commercial facilities had rather low power ratings, and some have been shut down. Commercial power reactors that have been closed include: Dresden, 1984; Fermi #1, 1973; Hallam, 1964; Humboldt Bay, 1983; Indian Point #1, 1980; and Pathfinder, 1967.

Table 1-B exhibits the data on mortality from 1950 through 1984 for the combined populations living near one or another of the 15 facilities; Table 2-B shows the detail in 5-year intervals. Since, for every one of these plants there are available at least fifteen, and for many more than twenty, years of mortality data after startup, deaths from radiation-induced cancer resulting from the plants' operations, if any, would not be missed because too little time has passed since the facilities began operations.

Among children below age 10, none of the RRs was significantly different from 1.00. For those between 10-19, the study area rate was significantly lower than for the control for leukemia (0.88) and Hodgkin's disease (0.68); for none was it higher.

At ages 20-39 none of the RRs comparing study and control areas after startup was significantly increased or decreased, nor was there any RR significantly in excess of unity comparing the study area after startup with that area before.

At ages 40-59, TBL cancer was marked by a significantly high RR of 1.05 comparing the study and control areas after startup; there were thousands of such deaths. The corresponding RR for brain cancer was significantly low -- 0.92. Cancer rates in the control areas apparently declined moderately after startup, manifested by RRs significantly less than 1.00 comparing the rates after with those before. At age 60+, four cancers were marked by significantly high RRs and one by a low RR; but there were also numerous other RRs that differed from 1.00 significantly, comparing the study and control areas before and after startup, and comparing the study and control areas before startup. Some of these RRs were larger than unity and some smaller. Table 2-B shows the data in 5-year intervals in relation to startup; there are no trends indicative of excess mortality in the study counties either before or after the beginning of operations of the facilities. Tables 1-B.1 to 1-B.15 and 2-B.1 to 2-B.15 contain the data for the individual facilities.

## C. Startup 1970-1974

Twenty-five commercial electricity-generating plants were put into service during the period 1970 to 1974 (Text Table 6). The power ratings of the earlier plants in this period were in the range 400 to 600 MWe, but by 1973, facilities with power ratings of 1000 MWe were beginning to come into service. The Kewaunee facility, in Kewaunee County, Wisconsin, is only about ten miles distant from the Point Beach facility in adjacent Manitowoc County; both are study counties for both facilities and, accordingly, they are treated together.

There were available, following startup, 15 years of mortality data, through the year 1984, for those facilities that began operations in 1970; for startup in 1974, only 10 years. Any excesses of leukemia ascribable to plant operations should be detectable, but the follow-up period is rather short for the detection of other forms of cancer that might have been induced.

Text Table 6
Electricity-generating Plants in Service 1970-1974

| | | Initially Critical* | Power Rating (MWe)** Initially | Units Added (and Year) | |
|---|---|---|---|---|---|
| 1. | Millstone | 1970 | 654 | 857, 1149 | (1975, 1986) |
| 2. | Point Beach/ | 1970 | 485 | 485 | (1972) |
| | Kewaunee | 1974 | 503 | | |
| 3. | Robinson | 1970 | 665 | 503 | (1974) |
| 4. | Monticello | 1971 | 536 | | |
| 5. | Palisades | 1971 | 730 | | |
| 6. | Maine Yankee | 1972 | 810 | | |
| 7. | Pilgrim | 1972 | 670 | | |
| 8. | Quad Cities | 1971 | 769 | 769 | (1972) |
| 9. | Surry | 1972 | 781 | 781 | (1973) |
| 10. | Turkey Point | 1972 | 666 | 666 | (1973) |
| 11. | Vermont Yankee | 1972 | 504 | | |
| 12. | Zion | 1973 | 1040 | 1040 | (1973) |
| 13. | Browns Ferry | 1973 | 1065 | 1065, 1065 | (1974, 1976) |
| 14. | Fort Calhoun | 1973 | 478 | | |
| 15. | Oconee | 1973 | 860 | 860, 860 | (1973) |
| 16. | Prairie Island | 1973 | 503 | 500 | (1974) |
| 17. | Arkansas | 1974 | 836 | 858 | (1978) |
| 18. | Calvert Cliffs | 1974 | 825 | 825 | (1976) |
| 19. | Cooper Station | 1974 | 764 | | |
| 20. | Duane Arnold | 1974 | 515 | | |
| 21. | Hatch | 1974 | 768 | 777 | (1978) |
| 22. | Peach Bottom | 1973 | 1051 | 1035 | (1974) |
| 23. | Rancho Seco | 1974 | 873 | | |
| 24. | Three Mile Island | 1974 | 776 | 906 | (1978) |

* Date of first sustained chain reaction.

** Reactor power is measured in several ways: Design rating, gross power output, net output etc. The numbers shown here reflect the approximate capacity of the reactors.

Source: DOE (1987).

Table 1-C shows the data for all 24 facilities combined, comparing the experience in the study and control areas and that prior to startup with that afterward.

No RRs comparing the study and control areas after startup were significantly different from unity for leukemia. This was true for both children and adults. At age 20-39 only the RR for bone and joint cancer was high -- 1.35. Among those aged 40-59, two of the RRs comparing the study and control areas after startup were below 1.00 and highly significant: for all cancer except leukemia (0.97) and for TBL cancer (0.92); the RRs were not very different from 1.00 but there were thousands of such deaths, which invested even such small discrepancies with "statistical significance".

Among persons over 60, there were in the study counties, significant deficits in deaths from all cancer except leukemia (0.98), and from stomach and TBL cancer, while colorectal cancer was apparently increased (1.03).

Table 2-C shows the data by five-year intervals. Again, there are several significant differences between study and control counties in the period after plant startup but, more often than not, the study county SMRs are smaller than those in the control counties.

## D. Startup 1975-1981

Twelve commercial electric facilities started operations in the years 1975 to 1981 inclusive (Text Table 7). Radiation-induced cancers other than leukemia generally do not cause death until at least ten years after exposure (BEIR, 1980). Therefore, if excess mortality from leukemia has occurred it would be detectable, but there is no opportunity, at this time, to observe any other excess cancers that might be attributable to the operations of these facilities even if they were induced by the very earliest operations. Data for the twelve facilities combined are shown in tables 1-D and 2-D.

Text Table 7
Electricity-generating Plants in Service 1975-1981

| | | Initially Critical* | Power Rating (MWe)** Initially | Units Added and (Year) | |
|---|---|---|---|---|---|
| 1. | Brunswick | 1975 | 790 | 790 | (1976) |
| 2. | Cook | 1975 | 1020 | 1060 | (1978) |
| 3. | Trojan | 1975 | 1050 | | |
| 4. | Fort St. Vrain | 1976 | 330 | | |
| 5. | Salem | 1976 | 1079 | 1106 | (1980) |
| 6. | St. Lucie | 1976 | 827 | 837 | (1983) |
| 7. | Crystal River | 1977 | 821 | | |
| 8. | Davis Besse | 1977 | 860 | | |
| 9. | Farley | 1977 | 827 | 829 | (1981) |
| 10. | North Anna | 1978 | 893 | 893 | (1980) |
| 11. | Sequoyah | 1980 | 1148 | 1148 | (1981) |
| 12. | McGuire | 1981 | 1150 | 1150 | (1983) |

* Date of first sustained chain reaction.

** Reactor power is measured in several ways: Design rating, gross power output, net output etc. The numbers shown here reflect the approximate capacity of the reactors.

Source: DOE (1987).

The combined data (Table 1-D) shows no evidence of excessive mortality from any form of leukemia at any age below 40. Among children below age 10 the RR for brain and other CNS neoplasms was significantly elevated, 2.02. For those aged 10-19 there were no significantly increased RRs. At ages 20-39, several RRs comparing the study and control areas after startup were significantly high -- all cancer except leukemia (1.12), "other" lymphoma (1.54) and TBL cancer (1.36).

At ages 40-59 there were no significantly high or low RRs. For those aged 60+, the RR for all cancer except leukemia was "significantly" low, 0.98. For all ages combined, no RR, for any form of cancer, was significantly increased after startup.

## INDIVIDUAL FACILITIES

The data for the individual facilities appear in Volumes 2 and 3. Volume 2 shows the number of observed deaths, the SMRs (or numbers of incident cancer cases and SRRs when the data are available) and the RRs for the periods before and after the startup of each facility. Volume 3 shows the data in five-year intervals before and after startup. All of the Department of Energy facilities appear first, in the order in which they began operations, followed by the commercial electricity-generating plants, also in sequence by date of startup; plants that started up in the same year appear alphabetically.

### Department of Energy Facilities

**Hanford** (Tables 1-A.1, 2-A.1).

The Hanford facility came into service in 1943 but there are no computerized data available concerning the cancer experience in the study counties prior to 1950. Recently it was acknowledged that very large amounts of radioactive iodine, perhaps more than 500,000 curies, were released into the environment from 1944 to 1955.

For children under 10, the RR for leukemia was only 1.15 and was not significantly larger than unity. At ages 10-19 no RRs differed significantly from 1.00, while at ages 20-39 and 40-59 mortality from all cancer except leukemia and from TBL cancer was significantly lower in the study than in the control counties. At ages 60+, a majority of the RRs comparing the study and control counties are less than one, but none differed from unity significantly. For all ages combined, the RR for all cancer except leukemia was "significantly" low, 0.96; whereas the RR for cancer of the bones and joints was significantly high, 1.51.

Table 2-A.1 displays the data (numbers of deaths and SMRs) for the Hanford facility, in 5-year intervals beginning in 1950. Similar tables for each facility use the year of startup to distribute the data in five-year intervals before and after. The SMRs for 1950-1953 and for 1954-1958 are untrustworthy because, as pointed out by Milham (1989), after 1950 the population of the area around Hanford increased greatly, peaked during the decade, and then declined by 1960. Therefore, the population estimates, which were based

on linear interpolation between the 1950 and 1960 census counts, substantially understated the true population and the SMRs are, in consequence, overstated.

**Oak Ridge** (Tables 1-A.2, 2-A.2).

The Oak Ridge National Laboratory started operations in 1943 so it is not possible to compare cancer mortality in the study counties before and after the laboratory began work. Although the RR for leukemia was 1.47 in children under 10, the excess was not statistically significant. The RR for leukemia was 1.02 for those aged 10-19. From Table 2-A.2 it can be seen that although there was much temporal variation, there was no evidence of a trend with time -- the SMRs were elevated during the earliest period for which data are available (1950-1953) and for thirty years thereafter. The only other noteworthy observations were in persons over age 40, where death from cancer of the trachea, bronchus and lung (TBL) was significantly increased in the study counties; above age 60, deaths from TBL cancer (1.24) and from all cancer except leukemia (1.06) were increased.

**Mound** (Tables 1-A.3, 2-A.3).

RRs for the population living near the Mound facility show no evidence of adverse health effects. There were a few "significant" differences, in different age groups, and for different diseases; some of the excesses were in the study counties and some in the controls. In particular, childhood leukemia seems not to have been affected. The reason is not a paucity of cases; there were, in the study area, 189 deaths from leukemia in children under 10 over the whole follow-up period. Among those at age 60+, there were four RRs that were significantly different from 1.00; three of the four were less than 1.00.

**Idaho National Engineering Laboratory** (Tables 1-A.4, 2-A.4).

INEL, like Hanford and some other DOE facilities, began operations before 1950, so no data are available for the period prior to startup. There was a single cancer for which the RR comparing the study counties with the control was significantly larger than 1.00: in the age group 10-19 the RR for bone and joint cancer was no less than 10.1 but this was caused, in large part, by an abnormally low SMR in the controls -- only 0.21, based

on a single case. There were also a few instances in which the RR was significantly less than one, notably for all cancer except leukemia at ages 40-59 and for TBL cancer in the same age group and also in the group 60+. The study and control counties were characterized alike by very low cancer mortality rates.

**Paducah Gaseous Diffusion** (Tables 1-A.5, 2-A.5).

No RRs for leukemia significantly exceeded 1.00 in any age group. In the 10-19 year age group the RR for bone and joint cancer was elevated (4.00) but this resulted, in part, from the very low SMR of 0.56 in the control counties. Among those 20-39 years the RR for cancer of the trachea, bronchus and lung (TBL) was significantly elevated. For those over 40, however, there were significantly increased RRs for colorectal cancer in the study counties. Adding together the data for all ages, a significant difference was found for death from colorectal cancer; the RR was 1.17 and the significance resulted from the large numbers of deaths in the two groups of counties, 585 and 2350, respectively. Similarly, liver cancer was significantly high (RR, 1.25).

**Savannah River** (Tables 1-A.6, 2-A.6).

There were no excesses of leukemia, or of any other form of cancer, in those below 10, or below 20. At ages 20-39 the RR for leukemia, 1.83, was significantly high. At ages 40-59 the only significantly increased RR, 1.16, was that for TBL cancer; the RR for TBL cancer was increased also in the 60+ age group, as was that for all cancer except leukemia and for bladder cancer. Among those in the 60+ age group, the RR for all cancer except leukemia was only 1.07, but was based on more than 3,000 deaths in the study counties and nearly 8,000 deaths in the control counties and was significantly different from 1.00. For all ages, stomach cancer was significantly low (RR, 0.84).

**Fernald (Feed Materials Production Center)** (Tables 1-A.7, 2-A.7).

The RR for leukemia among children under 10, comparing the study and control counties after startup, was 0.99. At ages 10-19 none of the RRs differed significantly from unity. At ages 20-39 the RRs for all cancer except leukemia (1.09), primary liver cancer (1.74) and female breast cancer (1.31) were all significantly larger than 1.00. At ages 40-

59 the numbers of deaths were quite large (more than 30,000 in the combined study and control groups after startup) and several RRs exceeded 1.00 at a level $P < 0.001$: for all cancer except leukemia, for digestive cancer as a whole, and specifically for colorectal cancer, for TBL cancer and cancer of the female breast. None of the RRs exceed 1.00 by very much -- the largest is 1.17 for colorectal cancer. It should be noted that at ages 40-59 the female breast cancer RR for study vs. control before startup was 1.55 and highly significant. For ages 60+, the RR for all cancer except leukemia was 1.11 before startup, larger than that after startup (1.09), and the RR for bladder cancer was 1.48 before, compared with 1.18 after startup. Several cancers were significantly high; the largest of these "excessive" RRs was 1.18. Hodgkin's disease was significantly low (RR, 0.78).

The Fernald plant began operations in 1951. Pre-startup data were available only for the two years 1950-1951, so the numbers of deaths before startup were much smaller than in any of the time intervals after startup. Nevertheless, even during this period, combining all ages, the RRs were significantly elevated above those for controls for all malignant neoplasms except leukemia and for cancers of the stomach, TBL, female breast, and bladder. Although the minimal latent period for death from radiation-induced solid cancers is at least ten years (BEIR, 1980; NIH, 1985), the SMRs for all cancers except leukemia changed little with time after startup -- in successive five-year periods the SMRs at age 60+ were all in the range 1.15 to 1.19 (Table 2-A.7). Excess cancers caused by emissions from operations of the Fernald plant, whether radioactive or other emissions, would be expected to increase in number with the passage of time, but there is little or no evidence of such an increase.

The Fernald Feed Materials Production Center is located northwest of the city of Cincinnati in Hamilton County, Ohio, not far from the boundary between Hamilton and Butler counties; both were study counties for Fernald (Butler County is also adjacent to the Mound facility). Data are shown below for deaths from cancer (except leukemia) for each of those counties, and their respective controls, for the periods 1950-1961 and 1962-1984 (Text Table 8). Any excess cancer deaths (other than from leukemia) that resulted from operation of Fernald would be expected to have occurred predominantly after 1961, allowing for a ten-year delay, even if cancers were induced very soon after the beginning of plant operation. It is evident that, although cancer mortality rates were high in Hamilton

County, the RRs were identically 1.11 before and after 1961, and identically highly significant both early and late. Moreover, there is no suggestion of increased cancer rates in Butler County, much of which is not far distant from Fernald. The RR for Butler was 1.02, which was "significantly" large before 1962, but was 1.00 in 1962-1984. Further, although some of the excess cancers are of the kind known to be inducible by radiation (of the digestive system, female breast and lung) the picture with respect to leukemia is confused.

Text Table 8
Feed Materials Processing Facility, Fernald
Deaths from All Cancer Except Leukemia
In Individual Study and Control Counties

| | 1950-1961 | | | 1962-1984 | | |
|---|---|---|---|---|---|---|
| County | Deaths | SMR | RR (P value) | Deaths | SMR | RR (P value) |
| Butler | 2519 | 1.005 | 1.02 | 7778 | 1.058 | 1.00 |
| Controls | 3805 | 0.986 | (0.02) | 11634 | 1.058 | (0.50) |
| Hamilton | 16718 | 1.181 | 1.11 | 41492 | 1.208 | 1.11 |
| Controls | 12495 | 1.060 | (<0.001) | 34756 | 1.090 | (<0.001) |

The city of Cincinnati is in Hamilton County and mortality rates in that city dominate the rates for the entire county. The plant is about 15 miles from the center of Cincinnati. Cancer mortality rates in Hamilton County are not very different from corresponding rates in other counties having large urban populations.

Text Table 9 displays age, sex and race-adjusted mortality rates in the decade 1950-1959 for Hamilton County in comparison with the rates for Cuyahoga County (Cleveland) and for Baltimore City:

Text Table 9
Selected Cancer Mortality Rates
Cancer mortality per 100,000, 1950-59

| | | |
|---|---|---|
| Hamilton County | (Cincinnati) | 186.1 |
| Cuyahoga County | (Cleveland) | 185.5 |
| Baltimore City | | 199.7 |
| State of Ohio | | 167.2 |

Source: Riggan et al. (1983).

**Portsmouth Gaseous Diffusion** (Table 1-A.8, 2-A.8).

RRs significantly different from unity, comparing the study and control counties were few in number. The RRs for stomach cancer were significantly high at ages 60+, and for all ages, in the study vs. control comparisons before startup and for control after vs. control before, in both instances because of abnormally low SMRs in the control counties before startup. For all ages, the RR for primary liver cancer (1.50) was significantly high, whereas the RR for breast cancer was significantly low (0.69).

**Rocky Flats** (Tables 1-A.9, 2-A.9).

Rocky Flats began operations in 1953 and is near Denver, Colorado. In 1969 there was a fire, and plutonium has been detected in the soil around the facility.

Among children below 10, three RRs were significantly less than 1.00; none was significantly larger. At ages 10-19, there were no RRs significantly high or low. At ages 20-39 one RR comparing the study and control counties after startup was significantly high -- for cancer of the brain and other CNS, but this occurred because the control SMR was very low after startup -- only 0.59. At ages 40-59 the RRs for "other" lymphoma and for colorectal cancer were significantly high, but were significantly low for stomach and primary liver cancer. At ages 60+, the RR for female breast cancer after startup was elevated (1.24) as was that for all cancer except leukemia (1.06). In both instances the significance resulted from a large number of deaths combined with a somewhat low SMR in the control counties. For female breast cancer, the study county SMR was 1.09 and the control SMR

was 0.88, and there were more than 1200 deaths in the two groups. For all cancer except leukemia the study SMR was only 0.90, but the control SMR was 0.85 so that the RR was 1.06; this, based upon nearly 14,000 deaths was highly significant. There were no significant differences between SMRs for study and control counties for leukemia, in any age group.

**Nuclear Fuel Services** (Tables 1-A.10, 2-A.10).

NFS was a private commercial fuel reprocessing facility located in West Valley, New York, about 30 miles from Buffalo. It operated from 1966 to 1972. The only significant difference between the study and control areas after startup in children below 10 was for all cancer except leukemia, where the RR of 2.68 comparing the two areas was significantly high. This resulted from the combination of a high SMR in the study area (SMR, 1.74; 14 deaths) and a low SMR in the control area (SMR, 0.65; 13 deaths). In the age groups 10-19 and 20-39 there were no significantly elevated (or depressed) RRs comparing the study and control areas after startup. At ages 60+, the RRs were elevated for all cancer except leukemia (1.08), cancer of the digestive organs and stomach cancer. The RR for stomach cancer, 1.46, was only a little larger than the RR of 1.39 (very highly significant) for that disease before startup; in both cases the significance derived in large part from low SMRs for that disease in the control areas both before and after startup.

## All Electric Utilities

Detailed data for individual electric utilities can be found in Volumes 2 and 3. Below are brief comments on the cancer mortality experience of residents living near each facility in comparison with that seen in the control counties. These commercial electricity-generating plants are in sequence by date of startup.

### Startup Before 1970

**Shippingport/Beaver Valley** (Tables 1-B.1, 2-B.1).

The nation's first commercial nuclear power plant began operating in 1957 in Beaver County, Pennsylvania. There was no evidence in the study counties of excessive leukemia

mortality at any age. Mortality in the study counties from all cancer except leukemia, for all ages and for age 60+, significantly exceeded that in control areas, but the RRs were only 1.03 and 1.06, respectively. Again, because of the many thousands of deaths in these areas even such small excesses of the RRs above 1.00 achieved statistical significance.

**Dresden** (Tables 1-B.2, 2-B.2).

There were no RRs significantly different from 1.00 in any of the age groups below 40. At age 40-59 the RR for TBL cancer was 1.22, and for all cancer except leukemia 1.06, comparing the study and control areas. At age 60+, TBL cancer was not increased in the study area and stomach cancer was increased. The RR for female breast cancer was less than 1.00. Leukemia was not increased in the study area in any age group.

**Yankee-Rowe** (Tables 1-B.3, 2-B.3).

No RR for leukemia, comparing mortality in the study and control areas after startup, in any age group, differed significantly from 1.00. The same was true for every form of cancer in all age groups below age 40. At ages 40-59 there were two RRs that differed significantly from 1.00: the RR for all cancer except leukemia was 0.93, significantly low, and that for thyroid cancer is 2.33, significantly high. At ages 60+, all of the significant RRs were low.

**Big Rock Point** (Tables 1-B.4, 2-B.4).

In the study counties for this facility no RR for persons less than age 40, for any form of cancer, differed significantly from 1.00. At ages 40-59 the RR for bladder cancer was 3.65, and significantly high, and at ages 60+ there were two such significantly elevated RRs: for all cancer except leukemia (1.07) and TBL cancer (1.18).

**Hallam** (Tables 1-B.5, 2-B.5).

In no age group below 60 was the RR for any form of cancer, comparing the study and control areas after startup, significantly in excess of 1.00. At age 60+, the RRs for all cancer except leukemia and for digestive cancer were significantly high as they were also before startup.

**Indian Point** (Tables 1-B.6, 2-B.6).

The Indian Point facility is in Westchester, NY and is adjacent to Rockland County, both with large populations. Unit 1, listed in Text Table 5, was joined in 1973 by Unit 2 and in 1976 by Unit 3. Although the numbers of deaths were large, in no age group below 60 was the RR significantly larger than 1.00. Although above age 60 the RR for "other" lymphoma was increased (1.12) the RR for all cancer except leukemia was only 0.98.

**Fermi** (Tables 1-B.7, 2-B.7).

Only one RR comparing the study and control areas after startup significantly exceeded 1.00. At age 60+, there were 62 deaths from liver cancer after startup; the RR was 1.47, which is significantly high, while the SMR was 1.35. The RR for all cancer other than leukemia for those 60+ was 0.92 and significantly low.

**Humboldt Bay** (Tables 1-B.8, 2-B.8).

The only RRs comparing the study and control areas after startup that were significantly larger than 1.00 were for female breast cancer at ages 20-39 (RR, 2.11), and, at age 60+, for all cancer except leukemia (RR, 1.08), all digestive cancers, generally (RR, 1.15), colorectal cancer (RR, 1.27) and female breast cancer (RR, 1.21). However, the RRs for all cancer except leukemia, for digestive cancer and for female breast cancer were also significantly above 1.00 before the plant startup.

**Pathfinder** (Tables 1-B.9, 2-B.9).

Pathfinder was a relatively low-power reactor (58 MWe) and was in service for only about three years. No RRs comparing the study and control areas after startup were significantly larger than 1.00 except for TBL cancer in those 40-59 and, at ages 60+, for all cancer except leukemia (RR, 1.08) and for all TBL cancer (RR, 1.13).

**Haddam Neck**

The Haddam Neck facility in Middlesex County, Connecticut, is one of the four for which cancer incidence data are available in addition to the data on cancer mortality. The generation of electricity began in 1967.

**Mortality Data** (Tables 1-B.10(MORT), 2-B.10(MORT)).

The only RRs comparing the study and control areas after startup, in specific age groups, that differed significantly from 1.00 were for colorectal cancer in those aged 20-39 (RR, 3.12, but the SMR in the study area was 1.34 while in the control it was only 0.43), for "other" lymphoma in those 40-59 (1.63) and, in the same age group, colorectal cancer (0.68) and,for those over 60 for Hodgkin's disease (only 0.34) and for TBL cancer (1.12).

**Incidence Data** (Tables 1-B.10(INC), 2-B.10(INC)).

No RRs comparing the study and control areas after startup for leukemia differed significantly from 1.00, in any age group. In specific age groups there were occasional RRs comparing the study and control areas after startup that significantly exceeded 1.00: at ages 20-39 for primary liver cancer (10.9, but the SMR in the study area was 3.50, based on 4 cases, while in the control area it was only 0.32, 1 case), for TBL cancer in those 40-59 and 60+ (RRs, 1.17 and 1.11) and, at age 60+ bladder cancer (RR, 1.14).

Interestingly, the pattern seen for both increases and decreases of cancers overall was similar for both mortality and incidence data. Comparing the RRs for Mortality and Incidence (study vs. control counties after startup) they were for leukemia, 1.13 vs. 1.06; for all cancer except leukemia, 0.98 vs. 1.05; for Hodgkin's disease, 0.52 vs. 0.66; for other lymphoma, 1.08 vs. 1.19; for TBL cancer 1.11 vs. 1.13; for thyroid, 1.22 vs. 1.39; and for bone and joint cancer, 2.00 vs. 1.59.

**La Crosse** (Tables 1-B.11, 2-B.11).

The La Crosse power station, rated at 48 MWe, is the lowest-power commercial electricity-generating facility. It is located in Vernon County, Wisconsin, a rural area having a small population, and, accordingly, the number of cancer deaths was not large. In fact, over the entire 35-year period for which data were available, there were only 89 deaths from all forms of leukemia and 1590 deaths from all cancer except leukemia. There were, on the average, fewer than three deaths from leukemia and only about 45 deaths from other cancers annually. There was no evidence of excessive cancer mortality in the study area.

**San Onofre** (Tables 1-B.12, 2-B.12).

The San Onofre plant, located in San Diego County, California, is in sharp contrast with La Crosse. The initial power rating of 436 MWe is about nine times as large, and the number of cancer deaths in the study area, more than 83,000, was more than 90 times the 908 in Vernon County, Wisconsin. San Onofre is located near San Clemente in San Diego County, close to the Orange County line, so both San Diego and Orange are study counties. With so large a population, even modest ratios of SMRs (RRs) can achieve statistical significance. Nevertheless, in the age groups under 40, there was no form of leukemia or other cancer for which, after startup, the RR comparing the study and control areas significantly exceeded unity. There were, however, two instances in which it was significantly lower: for bone and joint cancer and for Hodgkin's disease in children under 10 and for leukemia (all forms) in children aged 10-19. In the age group 40-59, RRs comparing the study and control areas after startup significantly exceeded 1.00 for all cancer except leukemia, "other" lymphoma and female breast cancer. In all three instances, however, the RRs were significantly raised before startup also, and there was little change in the study area SMRs from before to after startup -- in fact, in two instances the RRs comparing after startup with before in the study areas were less than 1.00. At ages 60+ there were three cases in which RRs comparing the study and control areas after startup exceeded 1.00 (all cancer except leukemia, "other" lymphoma and TBL cancer), but the RRs were little different from those before startup. For benign and unspecified neoplasms the RR was significantly low after startup in both age groups 40-59 and 60+.

**Ginna** (Tables 1-B.13, 2-B.13).

Wayne County, NY, where the Ginna plant is located, contains no large cities and, accordingly, the number of deaths from cancer was not large. Only in the age group above 60 years were there any statistically significant increases in RRs involving the study area after startup. In that age group the RRs comparing the study and control areas after startup significantly exceeded 1.00 for all cancer except leukemia, for TBL cancer and for stomach cancer; for the latter the RR was increased before startup as well as after.

**Nine Mile Point/Fitzpatrick** (Tables 1-B.14, 2-B.14).

The Nine Mile Point reactor went into service in 1969. It is located in Scriba, NY, not far from the city of Oswego. In 1976 a second plant was put into service on the same site; this was the Fitzpatrick facility, rated at 796 MWe. The tables treat startup as having occurred in 1969; there is no possibility of distinguishing any effects that might be attributable to Nine Mile Point from any for which Fitzpatrick might be responsible.

Among children under 10 years of age, deaths from all cancer except leukemia decreased significantly in the study county from before to after startup (RR, 0.19; 2 deaths). There were no notable differences in the 10-19 or 20-39 age groups, apart from an extremely low SMR for leukemia and aleukemia in the study county before startup for those 20-39 years of age. There were no significantly increased RRs comparing the study and control areas after startup at ages 40-59 or 60+. In the oldest age group, there were significant increases in the study county from before to after startup for all cancer except leukemia, digestive cancer and, in particular, for stomach cancer and for TBL cancer. The SMRs for these cancers before startup were rather low, ranging, for the four causes, from 0.73 to 0.94, and, after startup, from 1.00 to 1.08. Adding together all age groups, the picture is much like that for the age group 60+.

**Oyster Creek** (Tables 1-B.15, 2-B.15).

The Oyster Creek plant, rated at 620 MWe, is located in Ocean County, New Jersey, a populous area. There is no evidence of excessive mortality from childhood leukemia or from any other form of cancer in any age group below 40. At ages 40-59, there were significantly elevated RRs comparing the study and control areas after startup for all cancer except leukemia and for TBL cancer. For the latter two causes the RRs were significantly increased before startup as well as after. At ages 60+, there were several significantly increased RRs: for all cancer except leukemia, for TBL cancer and for digestive cancer, including, specifically, colorectal cancer. The RR for TBL cancer, however, was also increased before startup.

## Startup 1970-1974

### Millstone

The Millstone facility is located in New London County, Connecticut and, in addition to mortality data, incidence data are available. This facility started up in 1970. The Groton Naval Shipyard is also located in New London County.

**Mortality data** (Tables 1-C.1(MORT), 2-C.1(MORT)).

None of the RRs comparing the study and control areas after startup was significantly different from 1.00 in the age groups less than 10, 10-19 or 20-39. At ages 40-59 there were several RRs comparing the study and control areas after startup that were increased: for all cancer except leukemia, digestive cancer (including, specifically, colorectal cancer) and for TBL cancer. At age 60+, the RRs for all cancer except leukemia, and for TBL cancer were very significantly increased, but were so before startup also. The RRs were also increased for "other" lymphoma, digestive system and, specifically, colorectal cancer, and these were not increased before startup.

**Incidence data** (Tables 1-C.1(INC), 2-C.1(INC)).

One of the control counties for New London is Worcester, Massachusetts, for which incidence data are not available from the Connecticut tumor registry. Therefore, for incidence, the control counties are limited to the Connecticut counties of Litchfield and Tolland. The mortality and incidence data for the control counties are, therefore, not directly comparable.

The RR for leukemia in children under 10, comparing New London with the control counties after startup, was 3.04, significantly larger than 1.00. In part, the large RR reflects abnormally low incidence in the control counties (SRR, 0.51) but the SRR in New London was itself significantly increased, to 1.55. From Table 2-C.1(INC) it can be seen that the SRRs for leukemia were, in successive time periods, 1.46 in 1971-75, 1.34 in 1976-80 and 2.02 in 1981-84, based on a total of 44 cases. On the other hand, during the ten years before startup, 1961-1970, in New London there were 30 cases of leukemia in the children; and the SRR was elevated (1.34). In the children under 10, leukemia was increased after

startup in both males and females: in males, 25 cases (SRR, 1.50), and in females, 19 cases (SRR, 1.62). In the control areas, however, the incidence for children under age 10 (both sexes) was significantly below expectation at national SEER incidence rates: 15 cases (SRR, 0.51, $P < 0.01$). The cases, in the study area, were concentrated in the youngest children both before and after startup (Text Table 10). At ages 10-19, however, there were 14 cases in New London, SRR, 0.97 while in the control counties there were 12 cases (SRR, 0.75), and the ratio, RR, 1.29, was not significantly increased.

Text Table 10
Incident Cases of Childhood Leukemia
New London County

| Age | Number of Cases 1961-70 | 1971-84 |
|---|---|---|
| 0-4 | 16 | 27 |
| 5-9 | 14 | 17 |
| 10-14 | 3 | 6 |
| 15-19 | 1 | 8 |

In summary, children below 10, both males and females, had significantly elevated leukemia incidence rates, after startup, in comparison with the total SEER experience and also in comparison with the control counties. On the other hand, the incidence in the control counties was significantly below expectation at SEER rates. At the level of mortality, the RR for leukemia in children below age 10 was 1.84 and was not significant, while for incidence the RR for leukemia was 3.04 and was significant. The number of incident cases in New London was 44, while there were only 17 deaths, a number not large enough to return a statistically significant difference. Nevertheless, the RRs for incidence and for mortality both indicated that, in children below age 10, leukemia was more frequent in New London than in the control counties.

Forty-nine cases of leukemia were registered in children under 10 before startup in the study counties; the corresponding RR was 1.17, not significantly high. For all ages combined the RR of leukemia after startup was 1.05. There were no excesses for thyroid

cancer (RR, 0.94 based on 90 overall cases) or female breast cancer in any age group; in fact, for all ages combined, the RR for female breast cancer -- 0.93 -- was significantly below 1.00.

Other significantly increased RRs, comparing New London with the control counties were for the incidence of TBL cancer at ages 40-59, 60+, and all ages. The RRs were not extremely large, ranging from 1.14 to 1.25 in the three groups, but the number of incident cases was very large, 3,327 in total, so that even relatively small differences are highly significant. Colorectal cancer, too, showed small but significant differences based on more than 4,000 cases in the study and control areas.

**Point Beach/Kewaunee** (Tables 1-C.2, 2-C.2).

There were no significant differences between the study and control areas for deaths under age 40 and just one, a significant excess in mortality from bladder cancer at ages 40-59, which was less pronounced in the next age group and for all ages combined. The large RR (6.38) derives from a somewhat large SMR in the study area (1.85), combined with an abnormally low SMR in the control area (0.29). The large SMR in the study area was present even in the initial 5-year period after startup (Table 2-C.2). There were several differences between before and after startup in the study counties, but there were equal numbers of decreases and increases.

**Robinson** (Tables 1-C.3, 2-C.3).

Only two of the RRs comparing the study and control areas after startup were significantly different from 1.00: for leukemia at age 60+, where the RR was only 0.64, and at all ages combined, for female breast cancer (RR, 1.28). In the latter case, the SMR in the control area was only 0.76.

**Monticello** (Tables 1-C.4, 2-C.4).

There were no significantly raised RRs comparing study and control areas after startup.

**Palisades** (Tables 1-C.5, 2-C.5).

No RRs comparing the study and control areas after startup were significantly larger than 1.00. There were no deaths from leukemia in children below 10 in the study area after startup.

**Maine Yankee** (Tables 1-C.6, 2-C.6).

There were no significantly raised RRs comparing the study and control areas after startup.

**Pilgrim** (Tables 1-C.7, 2-C.7).

In no age group was there a significantly raised RR for leukemia comparing the study and control areas after startup; for all ages combined the leukemia RR of 0.87 was significantly low. The RR for all cancer except leukemia was increased for ages 20-39 (1.24); but there were a few RRs that were significantly low: for stomach cancer at ages 40-59, at 60+ and at all ages combined. The RR for TBL cancer was increased at 60+ (1.09).

**Quad Cities** (Tables 1-C.8, 2-C.8).

The total table, for all ages, shows a significant excess of liver cancer mortality after startup in the study area, a significant excess of cancer of the digestive organs (especially from liver cancer) but a deficit of female breast cancer. The RRs for leukemia for children under 10 are larger than 1.00, but are not significantly elevated and are, in fact, a trifle smaller than the RRs for the period before startup.

**Surry** (Tables 1-C.9, 2-C.9).

There was only a single significantly high RR comparing the study and control areas after startup; for all ages combined, the RR for TBL cancer comparing the study and control areas was 1.21.

**Turkey Point** (Tables 1-C.10, 2-C.10).

The Turkey Point facility is located in Dade County, Florida, some twenty or more miles south of Coral Gables, Miami and other cities. The county has a large population

and the number of deaths in the thirty-five-year study period was correspondingly large. Since most of the population resides far from the plant, only a very strong adverse effect could be expected to be perceptible in a study based on counties. Restricting attention to the period after startup, and to RRs comparing the study and control areas, there were no significant differences in the age groups below 20, whether for leukemia or other cancer; at ages 20-39, there was a significant deficit of deaths from TBL cancer (RR, 0.73). At 40-59 there were two highly significant excesses: for Hodgkin's disease (RR, 1.90) and for primary liver cancer (RR, 1.75). There were also two deficits: for all cancer except leukemia (RR, 0.88) and for TBL cancer (RR, 0.72). For ages 60+ and for all ages combined, there is a similar mixed picture, with some excesses and some deficits, characterized by very large numbers of deaths, which result in statistical significance for relatively small differences.

**Vermont Yankee** (Tables 1-C.11, 2-C.11).

There were few RRs comparing the study and control areas after startup that were significantly different from 1.00 either before or after the start of power generation at Vermont Yankee. At ages 10-19 the RRs for leukemia after plant startup were significantly low, 0.09. No RRs exceeded 1.00, for any form of cancer, in any age group.

**Zion** (Tables 1-C.12, 2-C.12).

Zion is located in Lake County, Illinois and is adjacent to Kenosha County, Wisconsin. These are fairly densely populated areas and there were many deaths over the 35-year period examined here. There were significantly elevated RRs comparing the study and control areas after startup for "other" lymphoma at ages 10-19 and 40-59, and for TBL cancer at ages 20-39, 40-59, and 60+ and for all ages combined. The increased RRs at ages 40 and over result from rather low SMRs in the control area both before and after startup. The SMRs for TBL cancer in the study area are not large, the largest being only 1.04 at ages 60+.

**Browns Ferry** (Tables 1-C.13, 2-C.13).

The number of deaths in the study counties was not large, and there was but a single significantly increased RR comparing the study and control areas after startup: for primary liver cancer summed over all ages the RR was 1.86.

**Fort Calhoun**

This facility is located in Washington County, Nebraska, on the Missouri River directly across from Harrison County, Iowa, which is also a study county. Harrison County is included in the area covered by the Iowa tumor registry, part of SEER, so that cancer incidence data were available in addition to data concerning mortality, but only for Harrison County. Therefore, the mortality data, which pertain to both counties, are not directly comparable with the incidence data. The facility started operations in 1973.

**Mortality Data** (Tables 1-C.14(MORT), 2-C.14(MORT)).

The number of deaths in the study counties after the startup of the facility was not large. There was not a single RR comparing the study and control areas after startup that was significantly high in any age group, for any kind of cancer. There were only two deaths attributed to leukemia in children below age 10, and none in those 10-19. For all ages combined there were only 36 deaths from leukemia and 618 from other malignant neoplasms. For no form of cancer, for any age group, was the RR significantly large or small.

**Incidence data** (Tables 1-C.14(INC), 2-C.14(INC)).

After startup, there were four cases of leukemia registered in children below age 10 in Harrison county and only one in the control area; although the RR was high, the value was not significantly different from unity. All four cases in Harrison county were in children below age 5; the SRR for children under 5 was 4.84 and this value significantly exceeds unity, $P = 0.01$, one-tail. Before startup (1973) registration data were sparse; there was but a single case of leukemia registered in Harrison County, and the SRR, 1.91, was

not significantly elevated. For all cancer except leukemia in children under 10, the RR comparing the study and control areas after startup was low (0.75) but this, too, was not significant.

There were no significant differences between Harrison County and its control counties for any other form of cancer. No RRs comparing the study and control areas after startup significantly exceeded unity, and only one was significantly low: for bladder cancer at ages 40-59, where no cases were registered, while there were 18 in the control area. For all ages together the RRs comparing the study and control areas after startup were 0.80 for leukemia and 0.95 for all other cancers.

**Oconee** (Tables 1-C.15, 2-C.15).

No RRs comparing the study and control areas after startup, for any form of cancer, significantly exceeded 1.00 in any age group below 40. The only significantly increased RRs were in the 40-59 year age group where the RR for non-Hodgkin's lymphoma was 2.07 and that for primary liver cancer was 4.15. The latter depended, in large part, on a very small SMR (0.40) in the control areas. The liver cancer SMR was also raised in the all ages total group (RR, 1.75).

**Prairie Island** (Tables 1-C.16, 2-C.16).

The numbers of cancer deaths were not large and there were few statistically significantly elevated RRs comparing the study and control areas after startup. None of the differences occurred in the group below age 40 but in the age group 40-59 the RR for leukemia was significantly high -- 2.41. In the age group 60+ and in the total at all ages the RRs for digestive cancer and, specifically, stomach cancer were significantly low.

**Arkansas** (Tables 1-C.17, 2-C.17).

The number of deaths after startup was small and there was no instance, for any kind of malignant neoplasm, where the RR in the study area significantly exceeded that in the control area after startup of the facility. For ages 40-59 and for all ages combined, the RR for cancer of the brain and other CNS was significantly low.

**Calvert Cliffs** (Tables 1-C.18, 2-C.18).

Cancer deaths were not numerous in the study area (Calvert County, Maryland): only 622 before startup and 567 after, at all ages, in 35 years. There was no instance where the RR comparing the study and control areas after startup differed significantly from 1.00.

**Cooper Station** (Tables 1-C.19, 2-C.19).

Deaths from malignant neoplasms were not very numerous in the study area after startup (732 for all cancer except leukemia). RRs were significantly larger than 1.00 only at ages 60+ and for all ages for all cancer except leukemia, multiple myeloma and TBL cancer. In all cases, however, the SMRs in the control area were fairly low, in some instances significantly less than 1.00.

**Duane Arnold**

The Duane Arnold nuclear facility, located in Linn County, Iowa, is adjacent to Benton County in the same state. Both incidence and mortality data are, therefore, available for both study counties and for the control counties. The facility began the production of electricity in 1974.

**Mortality data** (Tables 1-C.20(MORT), 2-C.20(MORT)).

Among children below 10 no RRs comparing the study and control areas after startup were significantly different from unity, for leukemia or any other kind of cancer. At ages 10-19 the RR for brain and other CNS cancer was significantly increased, to 4.16, on 12 such deaths. In no other age group was there a significantly raised RR. At ages 40-59, the RR for "other" lymphoma was significantly low (0.53).

**Incidence data** (Tables 1-C.20(INC), 2-C.20(INC)).

There were 17 incident cases of leukemia in children below age 10 in the study counties during 1975-1984, after startup in 1974. The RR was somewhat high -- 1.45 -- but was not significantly greater than 1.00. At ages 10-19 through 40-59, there were no RRs significantly different from 1.00. At age 60+, and for all ages combined, the RRs for all cancer except leukemia were increased (but only to 1.08 and 1.06) as they were also for

bladder cancer. The RR for TBL cancer was increased significantly only in the age group 60+. Before startup the RRs for all cancer except leukemia were significantly increased at age 60+, and for all ages, and were, in fact, slightly larger than those after startup: 1.10 and 1.08. For all ages combined the RRs before startup were significantly increased also for "other" lymphoma (1.34) and for TBL cancer (1.18).

The RRs comparing the study and control areas after startup were similar, based on mortality or incidence data, for all ages combined: leukemia, 1.02 in both; all cancer except leukemia, 1.02 and 1.06; digestive organ cancer, 1.03 in both; and bladder cancer, 1.21 and 1.27.

**Hatch** (Tables 1-C.21, 2-C.21).

The only RR significantly different from 1.00 was for Hodgkin's disease for all ages combined, 3.41, based on 7 deaths in each of the study and control areas after startup.

**Peach Bottom** (Tables 1-C.22, 2-C.22).

There were many hundreds of cancer deaths in the study and control areas after startup. Nevertheless, no RRs comparing the study and control areas after startup were significantly different from 1.00 in any age group below 60. At 60+, however, and for all ages, there were several RRs significantly different from 1.00, some larger and some smaller. The RRs were increased for all ages for colorectal cancer and female breast cancer and, for those 60+ only, for all cancer except leukemia (but only to 1.04). The RRs were decreased for stomach, primary liver and TBL cancers.

**Rancho Seco** (Tables 1-C.23, 2-C.23).

No RRs comparing the study and control areas after startup were significantly in excess of 1.00 in any age group below age 60. For ages 20-39, breast cancer was significantly low (RR, 0.70). In those above 60, and for all ages combined, the RR for bone and joint cancer was significantly increased; so also was the RR for TBL cancer, but TBL cancer was increased before startup as well and, in fact, the RR before startup was a trifle larger than that after. The RR for benign and unspecified neoplasms was very significantly below 1.00.

**Three Mile Island** (Tables 1-C.24, 2-C.24).

Operations at the Three Mile Island electric utility in Dauphin County, Pennsylvania, began in 1974. In the early morning of 28 March 1979 a loss-of-coolant accident at the Three Mile Island unit 2 resulted in the release, during the following two weeks, of approximately 2.4 million curies of both short- and long-lived fission products. Persons living within a few miles of the plant were exposed to external gamma radiation and to radionuclides that were inhaled and ingested. The radiation doses to such persons were small and estimated to average less than 20 mrem (0.2 mSv) and to have been less than 70 mrem (0.7 mSv) at a maximum (Kemeny, 1979). Local residents have been concerned about possible effects upon their health and that of their children, and several studies have been reported and some continue (Tokuhata, 1985).

The study area for this survey includes both Dauphin and the adjacent Lancaster and York counties. The Peach Bottom power plant is located in York County and both York and Lancaster are included in the study areas for both Three Mile Island and Peach Bottom.

The relative risk of death from leukemia in children under age 10 was 1.56, comparing the study and control areas after 1974, based on an SMR of 1.14 (28 deaths) in the study area but a low SMR of only 0.73, 63 deaths, in the controls. There was no excess mortality in children from other forms of cancer (RR, 1.04). At ages 10-19 the RRs were slightly less than unity: 0.87 and 0.90 for leukemia and other cancers respectively, and were also less than 1.00 at ages 20-39. The RR for death from leukemia for all ages combined was 1.00.

Concentrating attention on the last 5 years included in the survey, 1980-1984, after the 1979 accident, the RR for death from leukemia in children under age 10 was 1.56 (study area: SMR, 1.33, based on 14 deaths; control area: SMR, 0.85, based on 30 deaths) (Table 2-C.24). This RR is not significantly larger than 1.00. For the entire period after 1974, for the ages 40-59 the RRs for all cancer except leukemia and for TBL cancer were less than 1.00, and very significantly so, as they were also before startup. At ages 60+ and for all ages combined the RRs for several forms of cancer were significantly below 1.00 both after and before startup: for all cancer except leukemia, digestive cancer (and two of its components, stomach and primary liver cancer), for TBL cancer and for bladder cancer.

The only significantly increased RRs were for breast cancer in women aged 60+ (RR, 1.07) and for multiple myeloma at ages 60+ and for all ages combined (RR, 1.20 and 1.14, respectively).

## Startup 1975-1981

**Brunswick** (Tables 1-D.1, 2-D.1).

No RRs comparing the study and control areas after startup were significantly different from 1.00 at ages under 10 or 10-19. The only RR significantly increased was seen for digestive organ cancer among the age group 20-39. Death due to leukemia occurred significantly below expectation among those 60+ and for all ages combined.

**Cook** (Tables 1-D.2, 2-D.2).

There were no significantly increased RRs for leukemia. All five of the RRs significantly different from 1.00, after startup, were less than 1.00, reflecting lower risks in the study county.

**Trojan** (Tables 1-D.3, 2-D.3).

There were not very many deaths after 1975, and no RRs comparing the study and control areas after startup were significantly elevated above 1.00. For all ages combined, stomach cancer was significantly low (RR, 0.61).

**Fort St. Vrain** (Tables 1-D.4, 2-D.4).

No RRs comparing the study and control areas after startup were significantly increased; a few were decreased, however. In particular, all cancer except leukemia and cancer of TBL, above age 40 and for all ages taken together, had RRs significantly below 1.00.

**Salem** (Tables 1-D.5, 2-D.5).

At ages 40-59 only, the RR for leukemia was significantly increased after startup, as were also the RRs for all cancer except leukemia and digestive cancer. These were

isolated findings and, in particular, leukemia mortality in children below 10 was low, although not significantly so.

**St. Lucie** (Tables 1-D.6, 2-D.6).

The numbers of deaths in the study and control areas after startup were not large and no RRs comparing the study and control areas after startup were significantly elevated. Those for TBL cancer at ages 60+, and for all ages, were significantly low.

**Crystal River** (Tables 1-D.7, 2-D.7).

There were fewer than 1,500 deaths in the study area from any form of cancer, at any age, after startup, including only a single death from leukemia below age 20. No RRs comparing the study and control areas after startup, for any form of cancer, were significantly above or below 1.00.

**Davis Besse** (Tables 1-D.8, 2-D.8).

There were just two significantly increased RRs comparing the study and control areas after startup, for TBL cancer at ages 20-39 (13.4, based on 3 deaths in the study area and just 1 in the control area) and for bladder cancer at ages 40-59 (6.38, based on 5 and 3 deaths). In both instances the SMR in the control area was very low: at ages 20-39 the SMR for TBL cancer in the control area was only 0.22, and at ages 40-59 the SMR for bladder cancer in the control area was 0.64.

**Farley** (Tables 1-D.9, 2-D.9).

No RRs comparing the study and control areas after startup were significantly increased, whether for leukemia or any other form of cancer. A few comparisons were significantly less than 1.00: at ages 40-59 for all cancer except leukemia, colorectal cancer and female breast cancer; at 60+ for all cancer except leukemia and for digestive organ cancer; and for all ages combined, for those cancers and also for colorectal cancer.

**North Anna** (Tables 1-D.10, 2-D.10).

There were significantly elevated RRs comparing the study and control areas after startup for brain and other CNS tumors in the 40-59 year age group and at all ages. The RR for colorectal cancer was significantly low in the 40-59 year age group (0.49). There were, however, no significant excesses in any form of leukemia in any age group and, in fact, there were no deaths from leukemia in children under 10 in the study areas after startup.

**Sequoyah** (Tables 1-D.11, 2-D.11).

The Sequoyah plant went into service only in 1980, so there was no opportunity for any induced cancer, other than leukemia, to cause death before the end of 1984. No RRs for leukemia comparing the study and control areas after startup were, however, significantly increased. For cancers other than leukemia, there were four instances in which there were significantly increased RRs: at age under 10, for brain and other CNS cancer (RR, 12.8 on 5 deaths; the control SMR was only 0.27); at age 20-39, for all cancer except leukemia (1.38) and for brain and other CNS cancer (3.18); and, at age 60+, for stomach cancer and for female breast cancer. For all ages combined, there were significantly increased RRs for stomach cancer, primary liver cancer and female breast cancer. Before startup the RR comparing the study and control areas for all cancer except leukemia was significantly increased, but only to 1.03.

**McGuire** (Tables 1-D.12, 2-D.12).

There is no evidence of excess mortality from leukemia; in fact, there was only one death from leukemia under age 10 in the study area after startup. There were, however, a few significant differences between the study and control areas after startup: For all cancer except leukemia, at ages 10-19 (RR, 3.50) and at 20-39 (RR, 1.32). The discrepancy at ages 10-19 results from an extremely small SMR of 0.36 in the control counties. At ages 60+, and for all ages combined, the RRs for female breast cancer were significantly low: 0.78 and 0.85 in the two groups.

## DISCUSSION

This national survey was stimulated by the comprehensive study in the United Kingdom reported by the British Office of Population Censuses and Surveys (OPCS) (Cook-Mozaffari et al., 1987, Forman et al., 1987). The procedures and modes of analysis were different, and each study has some advantages. Advantages of the U.S. survey include the following: (1) A much longer time-frame -- 35 years, from 1950 to 1984 -- permitted more detailed analyses, including comparisons before and after reactor startup as well as comparisons with control areas and with the United States as a whole. (2) Although cancer registration (incidence) data were available to the OPCS survey, the authors' close examination of the data raised questions about the comparability of case ascertainment in various areas. In evaluating incidence in the U.S. survey, we have restricted attention to the limited set of facilities and counties for which SEER registration data of good quality are available. (3) There are many more nuclear facilities in the United States than in Great Britain.

The cancer mortality and incidence data reported here were derived from a survey, not an experimental study using randomization. It is not possible to choose control counties that, apart from the presence or absence of facilities, are truly comparable with the counties to which they are matched; counties vary with respect to the industries present, the occupations of their residents, their incomes, educational levels and ethnic composition and in other ways that can influence cancer incidence and mortality. The control counties were matched to the study counties by utilizing available data concerning racial composition, urban-rural mix, mean income, educational level and other factors; but no matching procedure, based on data that are not directly relevant to the basic etiologic factors that influence cancer incidence and mortality, can be an adequate substitute for randomization in an experimental study. Moreover, the data upon which the matching was based pertained to the years 1979 and 1980; the characteristics of particular counties in the 1950s and 1960s may have been different from those in 1979.

The cancer mortality in each county was also compared with the number of deaths expected on the basis of concurrent U.S. mortality rates and, when possible, the number of incident cases with the number expected on the basis of overall rates in the National

Cancer Institute's Surveillance, Epidemiology and End Results (SEER) program. National disease rates are, however, not necessarily an appropriate basis of comparison for particular counties that have their own individual characteristics with respect to smoking, drinking, occupation, diet, and other risk factors for cancer. Such issues are perhaps less important with respect to childhood leukemia than to adult cancers such as those of the lung or gastrointestinal system.

The question addressed is whether differences in mortality or incidence rates, associated with the presence of nuclear facilities in certain counties, can be detected for certain cancers. Because of the nature of this correlation survey, based on existing data, when differences unlikely to have been produced by chance are found, the conclusions can only be: Either the facilities affected the cancer rates, or the study counties differed from the controls (or from the United States as a whole) for other reasons, or perhaps both. Further, it is also possible that a real effect produced by a facility in a particular county might be obscured by variations caused by important but unknown factors such as exposures to hazardous levels of chemical pollutants. The analytic methods used treat each set, consisting of a study county (or counties) and the associated controls, as a stratum in which all departures from overall U.S. rates are the same. This cannot, however, be exactly true, and the data are, therefore, affected by so-called "extra-binomial" variation, that is, differences in county rates that arise from extraneous factors. It must be emphasized that the technical term "statistically significant" refers only to the question of whether the probability is smaller than a conventional 5 percent that a difference arose from mere chance; it says nothing about the cause of the difference, if it is real, and, in particular, has nothing to do with biological as opposed to mathematical significance. Many RRs have been noted to be significantly different from 1.00, but RRs close to 1.00, such as 0.98 or 1.03, even if "significant," have little meaning or biological relevance. Further, as noted previously, not only are the calculated relative risks affected by extra-binomial variation resulting from imperfect matching of control to study counties, but the fact that thousands of relative risks have been computed and tested for significance must be taken into account in assessing the meaning of those relative risks that achieve "statistical significance".

Beyond the weaknesses caused, inevitably, by the impossibility of perfectly matching controls to study counties, there are certain additional handicaps:

- Data were available only on a county basis. Especially in the West, many individual counties are very large and may measure 50 miles or more in length. The San Onofre power plant, for example, is in San Diego County but is located about 40 miles from the center of the city of San Diego. If it were true that there were cancer-causing effects associated with the San Onofre plant but that they extended only to a range of (say) five miles from the plant, such an effect would probably be impossible to detect because the county death rates are dominated by those of the very large population in distant San Diego city. In the Eastern states, however, counties are generally much smaller, and approximate the dimensions of the Health Districts in the United Kingdom used by Roman and colleagues (1987) in their study of the populations living near Harwell, Aldermaston and Burghfield.

- Although mortality data were available in each year, annual county population data needed for the calculation of cancer death rates had to be estimated using linear interpolation of data from successive decennial censuses, sample surveys and other related data. Year-to-year irregularities in age- and sex-specific population changes in particular counties affect the calculation of the numbers of deaths expected at U.S. rates.

- This study, of necessity, relied principally on mortality data; incidence data were available for only five counties, associated with four facilities. Mortality data, however, are inadequate for monitoring certain cancers, particularly thyroid cancer. With respect to childhood leukemia, improved therapy in recent years has markedly lowered death rates, while not affecting incidence. Further, improved survival for other cancers in recent years is unlikely to produce biased results although it does diminish the ability to detect the increased occurrence of disease. On the other hand, the U.K. survey that

stimulated the present investigation did identify significant excesses of deaths due to childhood leukemia.

- The kind of cancer that was the cause of death was obtained from physicians' statements on death certificates. These are not always entirely accurate. In particular, in the absence of an autopsy, it can be difficult to decide whether cancers of the lung or of the liver are primary to those organs or are metastatic from other sites. The quality of medical care available, and in particular, the proportion of deaths that follow hospital stays that are long enough to permit adequate evaluation, undoubtedly vary from county to county and affect the accuracy of cause-of-death certification and hence the comparability of county data. There is a special problem with respect to leukemia. In the 1950s and early 1960s the coding systems of the ICD placed all acute leukemia in a single rubric and the death of a child from acute lymphatic leukemia was classified simply as "acute leukemia", but if the attending physician wrote merely "lymphatic leukemia" on the certificate then the death would be coded as "lymphatic leukemia". Since the ability to distinguish between the subtypes of leukemia, especially of childhood leukemia, is limited in the early years, reliance has been placed on the category "all leukemia" instead of "lymphatic leukemia", whose interpretation is tenuous.

- Although a few Department of Energy facilities have been in operation for more than 40 years, the majority of the commercial electricity-generating plants came into service only in 1970 or later. Because of the long latent period for most cancers, only during the first few years of operation would it have been possible for plant emissions to induce cancers (other than leukemia) that would be detectable in the years prior to 1985.

Despite the limitations inherent in an "ecological" study of cancer mortality in counties with and without nuclear facilities, the methods used have been applied effectively

in the past to identify environmental carcinogens. For example, based on findings from the "cancer maps" constructed from county mortality statistics by the National Cancer Institute (Mason et al., 1975), a clustering of lung cancer deaths was seen among residents of counties along the South Atlantic coast. Across the United States, counties with shipyard industries were found to have elevated lung cancer death rates, particularly among men. Subsequent case-control studies in the high-risk areas linked the excess lung cancer deaths to asbestos exposure in shipyards, especially during World War II and in association with cigarette smoking (Blot et al., 1978). A similar approach was used to identify arsenical air pollution as an important cause of lung cancer in counties where non-ferrous ores are smelted and refined (Blot et al., 1975; Brown et al., 1984).

Each of the thousands of "relative risks" presented in our survey was subjected to statistical tests to assess the probability that its departure from 1.00 (in either direction) might have arisen as a random fluctuation, by mere chance. As could be expected, many turned out to be "significant" since if thousands of comparisons are made, about one percent of them will be "significant" at the one-percent level simply as a consequence of random variation, when there are actually no real differences. Since, however, it is not possible to choose "controls" that are perfect matches to study areas, when statistical tests point out that there are differences not readily ascribable to chance it remains to decide whether these differences, if real, are a direct consequence of the presence of nuclear facilities or result from other differences between areas. The fact that many significant differences were found for the period before facilities went into service illustrates the need for caution before interpreting the results as evidence of adverse health effects from the operation of the facilities. Help in interpretation is also available from the knowledge about radiation carcinogenesis that has been accumulated during the past 50 years, and especially the past 15 years. Although it is possible that radiation-induced leukemia can be manifested as soon as two years after exposure, cancers of other radiation-sensitive organs such as the female breast, lung, and thyroid gland do not develop as fast and are unlikely to be identified in mortality data for ten years or more after the radiation exposure to which they are attributable. Moreover, only with the passage of some years after the first operation of a facility can it be expected that residents of the surrounding area could

accumulate sufficient exposure to ionizing radiation or any other potentially harmful discharges, to induce a detectable increase in mortality from malignant neoplasms.

If conventional estimates of the cancer risks attributable to radiation are accepted, exposures from the monitored emissions from most nuclear facilities in the United States were much too small to result in detectable harm, typically less than 3 mrem/year to the maximally exposed individual (NCRP Report 92, 1987). They were, in fact, much smaller than the population exposures from natural background radiation (average about 100 mrem/year). On the other hand, some individual facilities, such as Hanford, apparently did release relatively large amounts of radioactivity into the environment. Whereas in Great Britain excess childhood leukemias were identified in the areas around the Sellafield and Dounreay reprocessing plants and the Aldermaston and Burghfield weapons facilities, significant excesses of childhood leukemia were not seen around similar U.S. installations in this survey, i.e., the DOE facilities.

In this study, a significant increase in childhood leukemia was found only in the incidence data available for the Millstone nuclear generating plant in New London, Connecticut. The relative risk, comparing the study county with the controls after startup in 1970, was 3.04, a statistically significant excess, based on 44 cases in New London county and 15 in the control counties (Table 1-C.1 (INC)). The standardized registration ratio (SRR) in the control counties was unusually low: 0.51, significantly less than 1.00, while in New London county it was 1.55. The probability that an SRR as large as 1.55 resulted simply from the operation of chance is less than one in one hundred; on the other hand, 65 such comparisons were made, so the finding is less persuasive -- the chance that one out of 65 such tests would be so extreme is about one in four. Examination of the time trends in Table 2-C.1(INC) reveals that the SRRs for leukemia in children under age 10 in New London county were increased even before the startup of Millstone in 1970:

| | | | STARTUP ⇓ | | |
|---|---|---|---|---|---|
| Period: | 1961-65 | 1966-70 | 1971-75 | 1976-80 | 1981-84 |
| Standardized Registration Ratio | 1.63 | 1.05 | 1.46 | 1.34 | 2.02 |

This survey has not proved that operations at any of the 62 nuclear facilities that have been studied have caused excess cases of childhood leukemia in their vicinity. In any case, besides the possibility of radioactive emissions, most of the Department of Energy installations utilize many chemical processes so that even if it could be shown that the plants are, in fact, responsible for the induction of leukemia or any other form of cancer, it is by no means certain that radioactive emissions could be implicated as the cause. In the case of Millstone, too, if the excess in childhood leukemia that has been observed was, in fact, not simply a result of chance, there may be other possible causes besides radiation, including particularly exposures to chemical pollutants. Further, other industrial or military complexes might exist in the same counties as those with nuclear installations, e.g., the Groton Naval Shipyard is in the same county as the Millstone nuclear power station, and these facilities might also contribute to any variations seen between areas in cancer rates. Such questions cannot be resolved by a correlational survey such as this one based on routinely available data.

Cook-Mozaffari and colleagues (1989b) found that, in England, and Wales, there were excesses of childhood leukemia and Hodgkin's disease in areas that had been proposed for nuclear facilities that had not been built, or were only built later, implying that such areas may be marked by unidentified risk factors other than those directly associated with the nuclear installations themselves.

Although public concerns have been raised with respect to Fernald, Rocky Flats, Hanford and Savannah River, this survey did not demonstrate cancer excesses associated with them. It should be emphasized, again, that the areas studied (counties) are of large size and this may have prevented finding possible excesses that characterize only smaller areas.

The survey did not detect any excesses of leukemia or other cancers in counties with commercial electricity-generating nuclear facilities except for New London County, Connecticut (Millstone). That facility was, however, one of only four for which cancer incidence data were available. Moreover, many commercial nuclear plants came into service only in 1970 or later and this survey had available to it, for most plants, only data on mortality through the year 1984. It should be recalled that for the Japanese survivors of the atomic bombs in Hiroshima and Nagasaki, it was only several years after the

bombings that it became clear that excessive numbers of cases of leukemia were occurring and it was only in 1967, 22 years after the exposures, that enough excess deaths from lung and female breast cancers had been reported to demonstrate the radiogenic risk.

Text Table 11 shows all of the individual facilities in which the relative risk of leukemia comparing the study and control areas after startup was, in some age groups, significantly different from unity. There were four instances in which the RR was larger than 1.00 and 14 in which it was less (the Turkey Point and Brunswick facilities each appear twice, for age 60+ and for all ages). Only one of the significant differences pertained to children below age 10, i.e., for the Millstone incidence data.

In some instances the RRs (ratios of the SMRs for study and control counties) either were significant because the control SMR was extremely small, or failed to achieve significance because the control SMR was itself very large. Every SMR for leukemia in the study counties for children under age 10, therefore, has been tested to see whether it was significantly larger than unity (Text Table 12). This was done for the period before as well as that after plant startup. It turned out that in 14 instances the SMR for leukemia in children under age 10 was increased significantly above unity; for three facilities this pertained to the period after startup only, in five, to before only and in three to both before and after. For three facilities the leukemia SMR was significantly lower than unity, in one case before startup and in two, after.

This study was initiated to learn whether the excesses of childhood leukemia that had been reported around the sites of certain nuclear facilities in Great Britain are also present in the United States. This study found no such pattern. For childhood leukemia, the relative risk comparing the study counties and their controls before plant startup was 1.08, a statistically significant increase, while after startup it was 1.03. For leukemia for all ages, the RRs were 1.02 before startup and 0.98 after startup. Thus, this survey did not detect any association between residence in a county with a nuclear facility and death attributable to leukemia.

Text Table 11
Facilities with Relative Risks
Significantly Different from 1.00
All Leukemia, Study vs. Control After Startup

| FACILITY | AGE GROUP | RELATIVE RISK |
|---|---|---|
| | | LARGER THAN 1.00 |
| Millstone (Incidence), CT | Under 10 | 3.04 |
| Savannah River, SC | 20-39 | 1.83 |
| Prairie Island, MN | 40-59 | 2.41 |
| Salem, NJ | 40-59 | 1.45 |
| | | LESS THAN 1.00 |
| San Onofre, CA | 10-19 | 0.75 |
| Quad Cities, IL | 10-19 | 0.29 |
| Vermont Yankee, VT | 10-19 | 0.09 |
| Hanford, WA | 40-59 | 0.71 |
| Mound, OH | 60+ | 0.92 |
| Robinson, SC | 60+ | 0.64 |
| Maine Yankee, ME | 60+ | 0.64 |
| Turkey Point, FL | 60+ | 0.88 |
| Brunswick, NC | 60+ | 0.15 |
| Fernald, OH | All | 0.94 |
| Humboldt Bay, CA | All | 0.47 |
| Turkey Point, FL | All | 0.93 |
| Pilgrim, MA | All | 0.87 |
| Brunswick, NC | All | 0.51 |

Text Table 12
Leukemia Mortality in Children Below Age 10
Facilities with SMR[a] Significantly Different from 1.00
Relative to Time of Startup

| FACILITY | SMR[a] Before | SMR[a] After | PROBABILITY (ONE-TAIL) |
|---|---|---|---|
| | | | LARGER THAN 1.00 |
| Hallam, NE | | 1.44 | 0.037 |
| Humboldt Bay, CA | 1.63 | | 0.023 |
| Rancho Seco, CA | 1.20 | | 0.009 |
| " " | | 1.52 | 0.004 |
| San Onofre, CA | 1.16 | | 0.006 |
| Zion, IL | 1.22 | | 0.032 |
| | | | SMALLER THAN 1.00 |
| Zion, IL | | 0.54 | 0.014 |

[a] Standardized mortality ratio: the ratio of the number of observed deaths to the number expected based on national statistics.

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## APPENDIX TABLE 1

Cause of Death Categories Used in the Analysis and Code Groups of the International Classification of Diseases (ICD)

| | Calendar Years | | |
|---|---|---|---|
| | 1950-1967 | 1968-1978 | 1979-1984 |
| ICD Revision | 6th, 7th | 8th | 9th |
| DIAGNOSTIC GROUPS | | | |
| Leukemia & aleukemia | 204 | 204-207 | 204-208 |
| Hodgkin's disease | 201 | 201 | 201 |
| Other lymphoma | 200,202,205 | 200,202 | 200,202 |
| Multiple myeloma | 203 | 203 | 203 |
| All Malignant Neoplasms Except Leukemia | 140-203 205 | 140-203 | 140-203 |
| Digestive Organs | 150-159 | 150-159,197.8 | 150-159 |
| Stomach | 151 | 151 | 151 |
| Colon & rectum | 153,154 | 153,154 | 153,154 |
| Liver (primary) | 155,156 | 155,197.8 | 155 |
| Trachea, bronchus & lung | 162,163 | 162 | 162 |
| Breast (female) | 170 | 174 | 174 |
| Thyroid | 194 | 193 | 193 |
| Bones and joints | 196 | 170 | 170 |
| Bladder | 181 exc. 181.7 | 188 | 188 |
| Brain and other CNS | 193 | 191,192.1-192.3, 225.0,225.2-225.4, 238.1 | 191,192.1-192.3, 225.0,225.2-225.4, 237.5,237.6 |
| Benign and Unspecified Neoplasms* | — | 210-239 | 210-234 |

* Benign and Unspecified Neoplasms (codes 210-239) are not available in the 6th or 7th revisions of the ICD and are in the 8th revision only starting in 1970.

## APPENDIX TABLE 2

Study Counties with Nuclear Facilities

| Nuclear Facility | County | State | Startup[a] |
|---|---|---|---|
| Arkansas | POPE | AR | 1974 |
| Big Rock Point | CHARLEVOIX | MI | 1962 |
| Browns Ferry | LIMESTONE | AL | 1973 |
| Brunswick | BRUNSWICK | NC | 1975 |
| Calvert Cliffs | CALVERT | MD | 1974 |
| Cook | BERRIEN | MI | 1975 |
| Cooper Station | NEMAHA | NE | 1974 |
| Crystal River | CITRUS | FL | 1977 |
| Davis Besse | OTTAWA | OH | 1977 |
| Dresden | GRUNDY | IL | 1960 |
| Duane Arnold | LINN | IA | 1974 |
| Farley | HOUSTON | AL | 1977 |
| Fermi | MONROE | MI | 1963 |
| Fernald | HAMILTON | OH | 1951 |
| Fort Calhoun | WASHINGTON | NE | 1973 |
| Fort St. Vrain | WELD | CO | 1976 |
| Ginna | WAYNE | NY | 1969 |
| Haddam Neck | MIDDLESEX | CT | 1967 |
| Hallam | LANCASTER | NE | 1962 |
| Hanford | BENTON | WA | 1943 |
| Hatch | APPLING | GA | 1974 |
| Humboldt Bay | HUMBOLDT | CA | 1963 |
| Idaho Nat. Eng. Lab. | BINGHAM | ID | 1949 |
| Idaho Nat. Eng. Lab. | BUTTE | ID | 1949 |
| Indian Point | WESTCHESTER | NY | 1962 |
| Kewaunee | KEWAUNEE | WI | 1973 |
| La Crosse (Genoa) | VERNON | WI | 1967 |
| Maine Yankee | LINCOLN | ME | 1972 |
| McGuire | MECKLENBURG | NC | 1981 |
| Millstone | NEW LONDON | CT | 1970 |
| Monticello | WRIGHT | MN | 1971 |
| Mound | MONTGOMERY | OH | 1947 |

[a]Year nuclear facility in study county began operating.

**APPENDIX TABLE 2 (continued)**

Study Counties with Nuclear Facilities

| Nuclear Facility | County | State | Startup[a] |
|---|---|---|---|
| Nine Mile Point | OSWEGO | NY | 1969 |
| North Anna | LOUISA | VA | 1978 |
| Nuclear Fuel Services | CATTARAUGUS | NY | 1966 |
| Oak Ridge | ANDERSON | TN | 1943 |
| Oak Ridge | ROANE | TN | 1943 |
| Oconee | OCONEE | SC | 1973 |
| Oyster Creek | OCEAN | NJ | 1969 |
| Paducah Gas. Diff. | BALLARD | KY | 1950 |
| Palisades | VAN BUREN | MI | 1971 |
| Pathfinder | MINNEHAHA | SD | 1964 |
| Peach Bottom | YORK | PA | 1974 |
| Pilgrim | PLYMOUTH | MA | 1972 |
| Point Beach | MANITOWOC | WI | 1970 |
| Portsmouth Gas. Diff. | PIKE | OH | 1952 |
| Prairie Island | GOODHUE | MN | 1973 |
| Quad Cities | ROCK ISLAND | IL | 1972 |
| Rancho Seco | SACRAMENTO | CA | 1974 |
| Robinson | DARLINGTON | SC | 1970 |
| Rocky Flats | JEFFERSON | CO | 1953 |
| St. Lucie | ST. LUCIE | FL | 1976 |
| Salem | SALEM | NJ | 1976 |
| San Onofre | SAN DIEGO | CA | 1967 |
| Savannah River | BARNWELL | SC | 1950 |
| Sequoyah | HAMILTON | TN | 1980 |
| Shippingport/Beaver Valley | BEAVER | PA | 1957 |
| Surry | SURRY | VA | 1972 |
| Three Mile Island | DAUPHIN | PA | 1974 |
| Trojan | COLUMBIA | OR | 1975 |
| Turkey Point | DADE | FL | 1972 |
| Vermont Yankee | WINDHAM | VT | 1972 |
| Yankee Rowe | FRANKLIN | MA | 1960 |
| Zion | LAKE | IL | 1972 |

[a]Year nuclear facility in study county began operating.

## APPENDIX TABLE 3

Study Counties Adjacent to Nuclear Facilities

| Nuclear Facility | Adjacent County | State | Startup[a] |
|---|---|---|---|
| Big Rock Point | EMMET | MI | 1962 |
| Browns Ferry | LAWRENCE | AL | 1973 |
| Cooper Station | ATCHISON | MO | 1974 |
| Cooper Station | RICHARDSON | NE | 1974 |
| Dresden | WILL | IL | 1960 |
| Duane Arnold | BENTON | IA | 1974 |
| Farley | EARLY | GA | 1977 |
| Fernald | BUTLER | OH | 1951 |
| Fort Calhoun | HARRISON | IA | 1973 |
| Fort St. Vrain | BOULDER | CO | 1976 |
| Fort St. Vrain | LARIMER | CO | 1976 |
| Hallam | GAGE | NE | 1962 |
| Hanford | FRANKLIN | WA | 1943 |
| Hanford | GRANT | WA | 1943 |
| Hatch | TOOMBS | GA | 1974 |
| Idaho Nat. Eng. Lab. | JEFFERSON | ID | 1949 |
| Indian Point | ROCKLAND | NY | 1962 |
| Kewaunee | MANITOWOC | WI | 1973 |
| Maine Yankee | SAGADAHOC | ME | 1972 |
| McGuire | GASTON | NC | 1981 |
| McGuire | LINCOLN | NC | 1981 |
| Monticello | SHERBURNE | MN | 1971 |
| Mound | BUTLER | OH | 1947 |
| Mound | WARREN | OH | 1947 |
| North Anna | CAROLINE | VA | 1978 |
| North Anna | HANOVER | VA | 1978 |

[a]Year nuclear facility in study county began operating.

**APPENDIX TABLE 3 (continued)**

Study Counties Adjacent to Nuclear Facilities

| Nuclear Facility | Adjacent County | State | Startup[a] |
|---|---|---|---|
| Oconee | PICKENS | SC | 1973 |
| Paducah Gas. Diff. | MCCRACKEN | KY | 1950 |
| Pathfinder | LINCOLN | SD | 1964 |
| Peach Bottom | LANCASTER | PA | 1974 |
| Point Beach | KEWAUNEE | WI | 1970 |
| Prairie Island | PIERCE | WI | 1973 |
| Quad Cities | WHITESIDE | IL | 1972 |
| Rancho Seco | AMADOR | CA | 1974 |
| Rancho Seco | SAN JOAQUIN | CA | 1974 |
| Robinson | CHESTERFIELD | SC | 1970 |
| Rocky Flats | BOULDER | CO | 1953 |
| Salem | NEW CASTLE | DE | 1976 |
| San Onofre | ORANGE | CA | 1967 |
| Savannah River | BURKE | GA | 1950 |
| Savannah River | AIKEN | SC | 1950 |
| Shippingport/Beaver Valley | HANCOCK | WV | 1957 |
| Surry | ISLE OF WIGHT | VA | 1972 |
| Three Mile Island | LANCASTER | PA | 1974 |
| Three Mile Island | YORK | PA | 1974 |
| Trojan | COWLITZ | WA | 1975 |
| Vermont Yankee | FRANKLIN | MA | 1972 |
| Vermont Yankee | CHESHIRE | NH | 1972 |
| Yankee Rowe | BERKSHIRE | MA | 1960 |
| Zion | KENOSHA | WI | 1972 |

[a]Year nuclear facility in study county began operating.

## APPENDIX TABLE 4

Study Counties and Control Counties by State

| State | Study County | Control County 1 | Control County 2 | Control County 3 |
|---|---|---|---|---|
| AL | HOUSTON | ELMORE | LEE | HOUSTON, GA |
| AL | LAWRENCE | LAMAR | PONTOTOC, MS | MAURY, TN |
| AL | LIMESTONE | COLBERT | GILES, TN | ALCORN, MS |
| AR | POPE | CRAWFORD | FAULKNER | BOONE |
| CA | AMADOR | TUOLUMNE | PLUMAS | SIERRA |
| CA | HUMBOLDT | MENDOCINO | SHASTA | SISKIYOU |
| CA | ORANGE | SANTA BARBARA | VENTURA | SAN BERNARDINO |
| CA | SACRAMENTO | SOLANO | CONTRA COSTA | SONOMA |
| CA | SAN DIEGO | SANTA BARBARA | SAN BERNARDINO | VENTURA |
| CA | SAN JOAQUIN | STANISLAUS | MERCED | MADERA |
| CO | BOULDER | EL PASO | DOUGLAS | GILPIN |
| CO | JEFFERSON | MESA | DOUGLAS | EL PASO |
| CO | LARIMER | EL PASO | PARK | MESA |
| CO | WELD | FREMONT | MORGAN | LOGAN |
| CT | MIDDLESEX | TOLLAND | LITCHFIELD | WINDHAM |
| CT | NEW LONDON | WORCESTER, MA | LITCHFIELD | TOLLAND |
| DE | NEW CASTLE | BALTIMORE, MD | ANNE ARUNDEL, MD | HOWARD, MD |
| FL | CITRUS | HERNANDO | CHARLOTTE | PASCO |
| FL | DADE | ORANGE | HILLSBOROUGH | DUVAL |
| FL | ST. LUCIE | ALACHUA | TAYLOR | COLUMBIA |
| GA | APPLING | WAYNE | BRYAN | COLQUITT |
| GA | BURKE | JEFFERSON | WASHINGTON | GREENE |
| GA | EARLY | BROOKS | SUMTER | CRISP |
| GA | TOOMBS | COFFEE | TIFT | LANIER |
| IA | BENTON | JACKSON | BREMER | BUCHANAN |
| IA | HARRISON | SHELBY | MONONA | GUTHRIE |
| IA | LINN | DES MOINES | MARSHALL | DUBUQUE |
| ID | BINGHAM | FREMONT | CASSIA | POWER |
| ID | BUTTE | MADISON, MT | BROADWATER, MT | CUSTER |
| ID | JEFFERSON | TWIN FALLS | LEMHI | ONEIDA |
| IL | GRUNDY | WOODFORD | JEFFERSON, WI | CASS, IN |
| IL | LAKE | DU PAGE | WAUKESHA, WI | KANE |
| IL | ROCK ISLAND | PEORIA | WINNEBAGO | TAZEWELL |
| IL | WHITESIDE | BOONE | FULTON | KNOX |
| IL | WILL | WINNEBAGO | PORTER, IN | McHENRY |

**APPENDIX TABLE 4 (continued)**

Study Counties and Control Counties by State

| State | Study County | Control County 1 | Control County 2 | Control County 3 |
|---|---|---|---|---|
| KY | BALLARD | LYON | STEWART, TN | McLEAN |
| KY | McCRACKEN | KNOX | HENDERSON | HOPKINS |
| MA | BERKSHIRE | HILLSBOROUGH, NH | RENSSELAER, NY | LITCHFIELD, CT |
| MA | FRANKLIN | RUTLAND, VT | MERRIMACK, NH | WINDSOR, VT |
| MA | PLYMOUTH | WORCESTER | BRISTOL | WASHINGTON, RI |
| MD | CALVERT | KING GEORGE, VA | TALBOT | WICOMICO |
| ME | LINCOLN | WALDO | FRANKLIN | HANCOCK |
| ME | SAGADAHOC | KNOX | KENNEBEC | CUMBERLAND |
| MI | BERRIEN | MUSKEGON | CALHOUN | CASS |
| MI | CHARLEVOIX | WEXFORD | ANTRIM | ALPENA |
| MI | EMMET | OTSEGO | IOSCO | BENZIE |
| MI | MONROE | ST. CLAIR | BAY | JACKSON |
| MI | VAN BUREN | NEWAYGO | MONTCALM | ST. JOSEPH |
| MN | GOODHUE | WASECA | WINONA | LE SUEUR |
| MN | SHERBURNE | ISANTI | NICOLLET | CHISAGO |
| MN | WRIGHT | CHISAGO | ISANTI | LE SUEUR |
| MO | ATCHISON | MORRIS, KS | NEMAHA, KS | DE KALB |
| NC | BRUNSWICK | HORRY, SC | BRYAN, GA | LEE |
| NC | GASTON | RUTHERFORD | STANLY | CATAWBA |
| NC | LINCOLN | DAVIE | POLK | ALEXANDER |
| NC | MECKLENBURG | GUILFORD | CRAVEN | WAKE |
| NE | GAGE | CLAY, KS | YORK | MERRICK |
| NE | LANCASTER | SALINE, KS | ADAMS | McPHERSON, KS |
| NE | NEMAHA | ANDREW, MO | LIVINGSTON, MO | OTOE |
| NE | RICHARDSON | NODAWAY, MO | SEWARD | JEFFERSON |
| NE | WASHINGTON | CASS | SEWARD | SAUNDERS |
| NH | CHESHIRE | BELKNAP | MERRIMACK | SULLIVAN |
| NJ | OCEAN | BUCKS, PA | NORTHAMPTON, PA | CAPE MAY |
| NJ | SALEM | ATLANTIC | GLOUCESTER | CAPE MAY |
| NY | CATTARAUGUS | GENESEE | STEUBEN | LIVINGSTON |
| NY | OSWEGO | LIVINGSTON | JEFFERSON | STEUBEN |
| NY | ROCKLAND | DUTCHESS | MIDDLESEX, NJ | NASSAU |
| NY | WAYNE | CAYUGA | ONTARIO | WYOMING |
| NY | WESTCHESTER | FAIRFIELD, CT | PASSAIC, NJ | UNION, NJ |
| OH | BUTLER | CLARK, IN | CLERMONT | CLARK |
| OH | HAMILTON | FRANKLIN | DELAWARE, IN | FLOYD, IN |

**APPENDIX TABLE 4 (continued)**

Study Counties and Control Counties by State

| State | Study County | Control County 1 | Control County 2 | Control County 3 |
|---|---|---|---|---|
| OH | MONTGOMERY | SUMMIT | MAHONING | STARK |
| OH | OTTAWA | HURON | SANDUSKY | SENECA |
| OH | PIKE | VINTON | MEIGS | GALLIA |
| OH | WARREN | CLERMONT | MIAMI | WAYNE, IN |
| OR | COLUMBIA | TILLAMOOK | CLATSOP | PACIFIC, WA |
| PA | BEAVER | ERIE | MERCER | WESTMORELAND |
| PA | DAUPHIN | CAMDEN, NJ | GLOUCESTER, NJ | ALLEGHENY |
| PA | LANCASTER | BERKS | NORTHAMPTON | WESTMORELAND |
| PA | YORK | LAWRENCE | MERCER | CAMBRIA |
| SC | AIKEN | DORCHESTER | LANCASTER | GREENWOOD |
| SC | BARNWELL | CHESTER | GEORGETOWN | SUMTER |
| SC | CHESTERFIELD | ABBEVILLE | KERSHAW | NEWBERRY |
| SC | DARLINGTON | BUTTS, GA | PUTNAM, GA | DILLON |
| SC | OCONEE | BARTOW, GA | STEPHENS, GA | FRANKLIN, GA |
| SC | PICKENS | HALL, GA | TRANSYLVANIA, NC | HABERSHAM, GA |
| SD | LINCOLN | COTTONWOOD, MN | JACKSON, MN | UNION |
| SD | MINNEHAHA | BLUE EARTH, MN | BEADLE | BROOKINGS |
| TN | ANDERSON | BLOUNT | BRADLEY | COFFEE |
| TN | HAMILTON | MADISON, AL | MONTGOMERY | DAVIDSON |
| TN | ROANE | HENDERSON, NC | JEFFERSON | HAMBLEN |
| VA | CAROLINE | ESSEX | WESTMORELAND | KING AND QUEEN |
| VA | HANOVER | GLOUCESTER | CLARKE | FAUQUIER |
| VA | ISLE OF WIGHT | MECKLENBURG | ESSEX | LUNENBURG |
| VA | LOUISA | NORTHUMBERLAND | LANCASTER | FLUVANNA |
| VA | SURRY | SUSSEX | BRUNSWICK | GATES, NC |
| VT | WINDHAM | RUTLAND | WINDSOR | ADDISON |
| WA | BENTON | SNOHOMISH | WALLA WALLA | WHITMAN |
| WA | COWLITZ | MASON | GRAYS HARBOR | CLARK |
| WA | FRANKLIN | DOUGLAS | YAKIMA | MORROW, OR |
| WA | GRANT | CHELAN | MALHEUR, OR | UMATILLA, OR |
| WI | KENOSHA | RACINE | SHEBOYGAN | ROCK |
| WI | KEWAUNEE | GREEN | MONROE | GREEN LAKE |
| WI | MANITOWOC | FOND DU LAC | SHEBOYGAN | CALUMET |
| WI | PIERCE | DUNN | ST. CROIX | POLK |
| WI | VERNON | BUFFALO | CRAWFORD | TREMPEALEAU |
| WV | HANCOCK | BROOKE | MARSHALL | OHIO |

## INDEX OF ALL NUCLEAR INSTALLATIONS INCLUDED IN THE STUDY

# SUMMARY TABLES

Table 1

Age at death: under 10 — All facilities combined

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 2020 | 1.07 | 4251 | 0.99 | 1390 | 1.01 | 2572 | 0.97 |
| ALL CANCER, EXCL LEUK | 1969 | 0.99 | 4623 | 1.03 | 1717 | 1.03 | 3243 | 1.02 |
| HODGKIN'S DISEASE | 42 | 1.33 | 69 | 0.95 | 13 | 0.75 | 26 | 0.78 |
| OTHER LYMPHOMA | 266 | 0.99 | 584 | 0.96 | 217 | 1.13 | 397 | 1.08 |
| MULTIPLE MYELOMA | 1 | 1.15 | 3 | 1.54 | 4 | 4.35 | 2 | 1.16 |
| DIGESTIVE ORGANS | 97 | 0.95 | 240 | 1.03 | 95 | 1.11 | 160 | 0.98 |
| STOMACH | 3 | 0.65 | 10 | 0.95 | 5 | 1.91 | 4 | 0.81 |
| COLON & RECTUM | 15 | 1.31 | 26 | 1.00 | 16 | 2.08 | 18 | 1.24 |
| LIVER (PRIMARY) | 59 | 0.99 | 141 | 1.04 | 57 | 0.96 | 113 | 1.00 |
| TRACHEA, BRONCHUS, LUNG | 13 | 0.79 | 44 | 1.17 | 26 | 1.58 | 19 | 0.61 |
| BREAST (FEMALE) | 2 | 0.76 | 14 | 2.34 | 5 | 1.57 | 4 | 0.66 |
| THYROID | 2 | 1.04 | 5 | 1.11 | 0 | 0.00 | 2 | 1.21 |
| BONES & JOINTS | 74 | 1.03 | 173 | 1.06 | 46 | 0.82 | 111 | 1.02 |
| BLADDER | 13 | 1.14 | 27 | 1.03 | 9 | 1.33 | 13 | 1.01 |
| BRAIN & OTHER C.N.S. | 808 | 1.02 | 1853 | 1.03 | 625 | 1.01 | 1208 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | 47 | 1.28 | 80 | 0.97 | 104 | 0.91 | 192 | 0.91 |

Table 1

Age at death: under 10 — All facilities combined

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.08** | 1.03 | 0.93 | 0.95 |
| ALL CANCER, EXCL LEUK | 0.94* | 0.99 | 1.05 | 0.96 |
| HODGKIN'S DISEASE | 1.41 | 0.90 | 0.94 | 0.99 |
| OTHER LYMPHOMA | 0.94 | 1.00 | 0.93 | 0.94 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.94 | 1.03 | 1.25 | 0.91 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | 1.70 | 1.52 | - | 1.60 |
| LIVER (PRIMARY) | 0.91 | 0.92 | 0.98 | 0.88 |
| TRACHEA, BRONCHUS, LUNG | 0.68 | 2.24** | 1.72 | 0.40** |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 1.04 | 0.78 | 0.95 | 0.96 |
| BLADDER | 1.20 | - | - | - |
| BRAIN & OTHER C.N.S. | 0.97 | 0.99 | 0.99 | 0.95 |
| BENIGN & UNSPEC NEOPLASMS | 1.39 | 1.02 | 0.75 | 0.92 |

* : $0.01 < P <= 0.05$
** : $0.001 < P <= 0.01$
*** : $P <= 0.001$

Table 1

Age at death: 10 to 19 — All facilities combined

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 923 | 1.01 | 2035 | 0.98 | 996 | 0.95 | 2063 | 1.02 |
| ALL CANCER, EXCL LEUK | 1684 | 0.96 | 3840 | 0.97 | 1963 | 1.01 | 3671 | 0.98 |
| HODGKIN'S DISEASE | 170 | 0.94 | 393 | 0.97 | 115 | 0.74 | 336 | 1.12 |
| OTHER LYMPHOMA | 263 | 1.03 | 545 | 0.94 | 286 | 1.02 | 547 | 1.01 |
| MULTIPLE MYELOMA | 1 | 0.90 | 0 | 0.00 | 3 | 2.21 | 5 | 1.90 |
| DIGESTIVE ORGANS | 77 | 0.88 | 210 | 1.07 | 105 | 1.12 | 150 | 0.85 |
| STOMACH | 1 | 0.16 | 7 | 0.48 | 9 | 1.68 | 6 | 0.59 |
| COLON & RECTUM | 27 | 0.79 | 82 | 1.08 | 32 | 1.00 | 47 | 0.78 |
| LIVER (PRIMARY) | 29 | 1.02 | 75 | 1.17 | 45 | 1.18 | 64 | 0.88 |
| TRACHEA, BRONCHUS, LUNG | 16 | 0.79 | 40 | 0.87 | 22 | 1.15 | 41 | 1.11 |
| BREAST (FEMALE) | 1 | 0.27 | 7 | 0.81 | 5 | 1.31 | 4 | 0.54 |
| THYROID | 2 | 0.42 | 12 | 1.11 | 3 | 0.73 | 9 | 1.13 |
| BONES & JOINTS | 294 | 0.90 | 726 | 0.99 | 362 | 1.02 | 640 | 0.94 |
| BLADDER | 0 | 0.00 | 5 | 1.38 | 0 | 0.00 | 1 | 0.36 |
| BRAIN & OTHER C.N.S. | 429 | 0.99 | 917 | 0.93 | 511 | 1.05 | 919 | 0.97 |
| BENIGN & UNSPEC NEOPLASMS | 36 | 1.19 | 67 | 0.96 | 75 | 0.87 | 167 | 1.04 |

Table 1

Age at death: 10 to 19 — All facilities combined

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.02 | 0.94 | 0.92 | 1.05 |
| ALL CANCER, EXCL LEUK | 0.98 | 1.03 | 1.03 | 0.97 |
| HODGKIN'S DISEASE | 1.01 | 0.69** | 0.83 | 1.07 |
| OTHER LYMPHOMA | 1.11 | 0.99 | 0.94 | 0.97 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.84 | 1.30* | 1.38 | 0.77* |
| STOMACH | - | - | - | - |
| COLON & RECTUM | 0.70 | 1.37 | 1.31 | 0.61* |
| LIVER (PRIMARY) | 0.91 | 1.39 | 1.30 | 0.82 |
| TRACHEA, BRONCHUS, LUNG | 0.89 | 1.05 | 1.54 | 1.30 |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 0.91 | 1.11 | 1.03 | 0.95 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 1.01 | 1.05 | 1.06 | 1.00 |
| BENIGN & UNSPEC NEOPLASMS | 1.30 | 0.82 | 0.70 | 1.12 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1

Age at death: 20 to 39 — All facilities combined

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 1391 | 0.98 | 2939 | 0.93 | 1834 | 1.01 | 3395 | 1.02 |
| ALL CANCER, EXCL LEUK | 12301 | 0.97 | 27881 | 0.99 | 14346 | 0.99 | 26853 | 1.01 |
| HODGKIN'S DISEASE | 1151 | 1.02 | 2625 | 1.05 | 1121 | 1.03 | 2230 | 1.11 |
| OTHER LYMPHOMA | 682 | 0.97 | 1556 | 1.00 | 974 | 1.06 | 1735 | 1.02 |
| MULTIPLE MYELOMA | 60 | 1.08 | 135 | 1.10 | 71 | 1.12 | 126 | 1.09 |
| DIGESTIVE ORGANS | 2004 | 0.93 | 4920 | 1.02 | 2076 | 0.94 | 3926 | 0.98 |
| STOMACH | 373 | 0.83 | 1012 | 1.01 | 345 | 0.88 | 626 | 0.87 |
| COLON & RECTUM | 997 | 0.95 | 2411 | 1.03 | 982 | 0.93 | 1979 | 1.02 |
| LIVER (PRIMARY) | 226 | 1.02 | 482 | 0.99 | 262 | 1.12 | 424 | 1.01 |
| TRACHEA, BRONCHUS, LUNG | 897 | 0.93 | 2110 | 0.99 | 1293 | 0.99 | 2373 | 0.99 |
| BREAST (FEMALE) | 1714 | 0.98 | 3941 | 1.01 | 2155 | 1.01 | 4058 | 1.02 |
| THYROID | 40 | 0.96 | 93 | 1.00 | 44 | 1.10 | 84 | 1.14 |
| BONES & JOINTS | 251 | 1.07 | 503 | 0.97 | 332 | 1.15 | 510 | 0.97 |
| BLADDER | 63 | 1.15 | 117 | 0.96 | 52 | 1.06 | 106 | 1.17 |
| BRAIN & OTHER C.N.S. | 1051 | 0.96 | 2295 | 0.93 | 1317 | 0.98 | 2452 | 0.99 |
| BENIGN & UNSPEC NEOPLASMS | 64 | 0.87 | 170 | 1.05 | 231 | 0.92 | 429 | 0.97 |

Table 1

Age at death: 20 to 39 — All facilities combined

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.05 | 1.01 | 1.05 | 1.10** |
| ALL CANCER, EXCL LEUK | 1.01 | 1.00 | 1.02 | 1.01 |
| HODGKIN'S DISEASE | 1.03 | 0.99 | 1.01 | 1.01 |
| OTHER LYMPHOMA | 1.00 | 1.07 | 1.05 | 0.97 |
| MULTIPLE MYELOMA | 0.98 | 1.16 | 0.98 | 1.05 |
| DIGESTIVE ORGANS | 0.95 | 0.98 | 1.00 | 0.94* |
| STOMACH | 0.84** | 0.96 | 1.10 | 0.87* |
| COLON & RECTUM | 0.98 | 0.94 | 0.96 | 0.95 |
| LIVER (PRIMARY) | 1.09 | 1.13 | 1.06 | 1.05 |
| TRACHEA, BRONCHUS, LUNG | 0.94 | 1.01 | 1.08 | 1.00 |
| BREAST (FEMALE) | 1.02 | 1.00 | 0.98 | 1.04 |
| THYROID | 0.95 | 1.00 | 1.22 | 1.16 |
| BONES & JOINTS | 1.16 | 1.27** | 1.09 | 0.99 |
| BLADDER | 1.37 | 0.80 | 0.92 | 1.24 |
| BRAIN & OTHER C.N.S. | 1.00 | 1.01 | 0.98 | 1.03 |
| BENIGN & UNSPEC NEOPLASMS | 0.84 | 0.99 | 1.21 | 0.87 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1

Age at death: 40 to 59 — All facilities combined

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 3162 | 0.98 | 7271 | 0.97 | 3792 | 1.00 | 7517 | 1.01 |
| ALL CANCER, EXCL LEUK | 91496 | 0.99 | 214260 | 1.00 | 120112 | 1.00 | 236862 | 1.00 |
| HODGKIN'S DISEASE | 1184 | 0.94 | 2979 | 1.02 | 1016 | 0.97 | 2205 | 1.06 |
| OTHER LYMPHOMA | 2899 | 1.05 | 6220 | 0.97 | 3773 | 1.02 | 7548 | 1.03 |
| MULTIPLE MYELOMA | 1021 | 1.00 | 2317 | 0.98 | 1459 | 1.00 | 2776 | 0.97 |
| DIGESTIVE ORGANS | 24499 | 0.98 | 58745 | 1.01 | 27512 | 1.00 | 55120 | 1.02 |
| STOMACH | 4489 | 0.92 | 11369 | 1.00 | 3843 | 0.93 | 8204 | 1.02 |
| COLON & RECTUM | 10849 | 1.02 | 25868 | 1.04 | 12379 | 1.03 | 24937 | 1.04 |
| LIVER (PRIMARY) | 2442 | 0.96 | 5917 | 1.00 | 1840 | 0.96 | 3447 | 0.92 |
| TRACHEA, BRONCHUS, LUNG | 17817 | 0.98 | 41177 | 0.98 | 32946 | 1.01 | 63239 | 0.98 |
| BREAST (FEMALE) | 12864 | 1.00 | 30135 | 1.01 | 17327 | 1.05 | 33717 | 1.03 |
| THYROID | 260 | 0.85 | 767 | 1.07 | 303 | 1.07 | 578 | 1.03 |
| BONES & JOINTS | 512 | 0.95 | 1241 | 0.99 | 398 | 0.92 | 805 | 0.95 |
| BLADDER | 1485 | 1.04 | 3545 | 1.07 | 1467 | 1.03 | 2991 | 1.06 |
| BRAIN & OTHER C.N.S. | 3404 | 1.01 | 7780 | 0.99 | 4142 | 0.97 | 8455 | 0.99 |
| BENIGN & UNSPEC NEOPLASMS | 259 | 1.01 | 724 | 1.20 | 764 | 0.94 | 1522 | 0.97 |

Table 1

Age at death: 40 to 59 — All facilities combined

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.01 | 1.00 | 1.02 | 1.03 |
| ALL CANCER, EXCL LEUK | 1.01 | 1.01 | 0.98*** | 0.99 |
| HODGKIN'S DISEASE | 0.97 | 0.97 | 1.06 | 1.06 |
| OTHER LYMPHOMA | 1.10*** | 1.00 | 0.95 | 1.04* |
| MULTIPLE MYELOMA | 1.01 | 1.04 | 0.96 | 0.97 |
| DIGESTIVE ORGANS | 1.01 | 1.00 | 1.00 | 1.00 |
| STOMACH | 0.96* | 0.94** | 1.04 | 1.02 |
| COLON & RECTUM | 1.04*** | 1.02 | 0.98 | 1.00 |
| LIVER (PRIMARY) | 0.98 | 1.03 | 0.96 | 0.89*** |
| TRACHEA, BRONCHUS, LUNG | 1.00 | 1.01 | 0.96*** | 0.99 |
| BREAST (FEMALE) | 1.01 | 1.03** | 1.00 | 1.01 |
| THYROID | 0.84* | 1.08 | 1.13 | 0.91 |
| BONES & JOINTS | 1.00 | 0.98 | 1.03 | 0.97 |
| BLADDER | 0.98 | 0.98 | 1.00 | 0.98 |
| BRAIN & OTHER C.N.S. | 1.01 | 0.96* | 0.95 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | 0.89 | 0.99 | 0.91 | 0.79*** |

* : $0.01 < P \leq 0.05$
** : $0.001 < P \leq 0.01$
*** : $P \leq 0.001$

Table 1

Age at death: 60 plus — All facilities combined

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 8511 | 0.97 | 19475 | 0.96 | 13164 | 0.97 | 27027 | 1.01 |
| ALL CANCER, EXCL LEUK | 226750 | 0.98 | 545906 | 1.02 | 366155 | 1.03 | 727345 | 1.03 |
| HODGKIN'S DISEASE | 1294 | 0.92 | 3512 | 1.07 | 1413 | 0.98 | 2915 | 1.01 |
| OTHER LYMPHOMA | 5898 | 1.07 | 12341 | 0.97 | 10923 | 1.04 | 20836 | 1.00 |
| MULTIPLE MYELOMA | 2761 | 1.00 | 6350 | 1.00 | 5911 | 1.01 | 11725 | 1.03 |
| DIGESTIVE ORGANS | 87127 | 0.97 | 216422 | 1.03 | 118266 | 1.03 | 237648 | 1.05 |
| STOMACH | 18275 | 0.92 | 47868 | 1.03 | 16812 | 0.97 | 35806 | 1.04 |
| COLON & RECTUM | 40155 | 1.00 | 98425 | 1.05 | 59642 | 1.07 | 117639 | 1.06 |
| LIVER (PRIMARY) | 8446 | 0.93 | 21444 | 1.01 | 6845 | 0.98 | 13588 | 0.97 |
| TRACHEA, BRONCHUS, LUNG | 34903 | 0.99 | 80480 | 0.99 | 83459 | 1.03 | 162094 | 1.01 |
| BREAST (FEMALE) | 17262 | 0.99 | 40956 | 1.02 | 29239 | 1.07 | 57209 | 1.06 |
| THYROID | 902 | 0.96 | 2143 | 0.98 | 1127 | 1.04 | 2213 | 1.04 |
| BONES & JOINTS | 1218 | 0.95 | 3077 | 1.02 | 1079 | 0.97 | 2155 | 0.97 |
| BLADDER | 9023 | 1.06 | 21613 | 1.09 | 12224 | 1.07 | 24187 | 1.07 |
| BRAIN & OTHER C.N.S. | 2758 | 1.04 | 5793 | 0.94 | 6375 | 1.03 | 12517 | 1.02 |
| BENIGN & UNSPEC NEOPLASMS | 543 | 1.01 | 1265 | 1.00 | 2229 | 1.01 | 4647 | 1.10 |

Table 1

Age at death: 60 plus — All facilities combined

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.00 | 0.97** | 0.99 | 1.04*** |
| ALL CANCER, EXCL LEUK | 0.99 | 1.01 | 1.02*** | 1.01 |
| HODGKIN'S DISEASE | 0.87*** | 0.96 | 1.15** | 0.95 |
| OTHER LYMPHOMA | 1.09*** | 1.04** | 0.97 | 1.03* |
| MULTIPLE MYELOMA | 0.98 | 0.98 | 1.01 | 1.02 |
| DIGESTIVE ORGANS | 0.98*** | 1.01 | 1.04*** | 1.01 |
| STOMACH | 0.94*** | 0.97** | 1.08*** | 1.03*** |
| COLON & RECTUM | 1.01 | 1.04*** | 1.03*** | 1.00 |
| LIVER (PRIMARY) | 0.95*** | 1.01 | 0.99 | 0.95*** |
| TRACHEA, BRONCHUS, LUNG | 1.00 | 1.01 | 0.99 | 1.01 |
| BREAST (FEMALE) | 1.01 | 1.03*** | 1.04*** | 1.03*** |
| THYROID | 1.00 | 1.02 | 1.04 | 1.02 |
| BONES & JOINTS | 0.99 | 1.03 | 1.02 | 0.96 |
| BLADDER | 1.01 | 1.02 | 0.98 | 0.98* |
| BRAIN & OTHER C.N.S. | 1.06* | 0.99 | 0.95 | 1.09*** |
| BENIGN & UNSPEC NEOPLASMS | 1.03 | 0.95* | 1.01 | 1.05 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1

Age at death: all — All facilities combined

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 16007 | 0.99 | 35971 | 0.97 | 21176 | 0.98 | 42574 | 1.01 |
| ALL CANCER, EXCL LEUK | 334200 | 0.99 | 796510 | 1.01 | 504293 | 1.02 | 997974 | 1.02 |
| HODGKIN'S DISEASE | 3841 | 0.96 | 9578 | 1.04 | 3678 | 0.98 | 7712 | 1.06 |
| OTHER LYMPHOMA | 10008 | 1.05 | 21246 | 0.97 | 16173 | 1.04 | 31063 | 1.01 |
| MULTIPLE MYELOMA | 3844 | 1.00 | 8805 | 1.00 | 7448 | 1.01 | 14634 | 1.02 |
| DIGESTIVE ORGANS | 113804 | 0.97 | 280537 | 1.03 | 148054 | 1.02 | 297004 | 1.04 |
| STOMACH | 23141 | 0.92 | 60266 | 1.03 | 21014 | 0.96 | 44646 | 1.03 |
| COLON & RECTUM | 52043 | 1.00 | 126812 | 1.05 | 73051 | 1.06 | 144620 | 1.06 |
| LIVER (PRIMARY) | 11202 | 0.94 | 28059 | 1.01 | 9049 | 0.98 | 17636 | 0.96 |
| TRACHEA, BRONCHUS, LUNG | 53646 | 0.99 | 123851 | 0.99 | 117746 | 1.03 | 227766 | 1.00 |
| BREAST (FEMALE) | 31843 | 1.00 | 75053 | 1.02 | 48731 | 1.06 | 94992 | 1.05 |
| THYROID | 1206 | 0.93 | 3020 | 1.00 | 1477 | 1.05 | 2886 | 1.04 |
| BONES & JOINTS | 2349 | 0.96 | 5720 | 1.01 | 2217 | 0.99 | 4221 | 0.96 |
| BLADDER | 10584 | 1.06 | 25307 | 1.09 | 13752 | 1.07 | 27298 | 1.07 |
| BRAIN & OTHER C.N.S. | 8450 | 1.01 | 18638 | 0.97 | 12970 | 1.00 | 25551 | 1.00 |
| BENIGN & UNSPEC NEOPLASMS | 949 | 1.02 | 2306 | 1.05 | 3403 | 0.98 | 6957 | 1.05 |

Table 1

Age at death: all — All facilities combined

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.02 | 0.98* | 0.99 | 1.04*** |
| ALL CANCER, EXCL LEUK | 1.00 | 1.01 | 1.01 | 1.01 |
| HODGKIN'S DISEASE | 0.96* | 0.96 | 1.07* | 1.01 |
| OTHER LYMPHOMA | 1.08*** | 1.03** | 0.97* | 1.03** |
| MULTIPLE MYELOMA | 0.99 | 1.00 | 0.99 | 1.01 |
| DIGESTIVE ORGANS | 0.99 | 1.01 | 1.03*** | 1.01 |
| STOMACH | 0.95*** | 0.97*** | 1.07*** | 1.03*** |
| COLON & RECTUM | 1.02*** | 1.03*** | 1.02** | 1.00 |
| LIVER (PRIMARY) | 0.96*** | 1.02 | 0.99 | 0.94*** |
| TRACHEA, BRONCHUS, LUNG | 0.99 | 1.01 | 0.98** | 1.01 |
| BREAST (FEMALE) | 1.01 | 1.03*** | 1.02** | 1.03*** |
| THYROID | 0.96 | 1.03 | 1.06 | 1.00 |
| BONES & JOINTS | 1.00 | 1.05 | 1.03 | 0.96 |
| BLADDER | 1.01 | 1.02 | 0.98 | 0.98* |
| BRAIN & OTHER C.N.S. | 1.02 | 0.98 | 0.96* | 1.04*** |
| BENIGN & UNSPEC NEOPLASMS | 0.99 | 0.96 | 0.97 | 0.97 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-A

Age at death: under 10 Department of Energy facilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 39 | 1.18 | 48 | 0.84 | 601 | 1.01 | 1009 | 0.96 |
| ALL CANCER, EXCL LEUK | 37 | 1.06 | 56 | 0.93 | 660 | 0.99 | 1233 | 1.05 |
| HODGKIN'S DISEASE | 1 | 1.45 | 2 | 1.76 | 5 | 0.56 | 9 | 0.56 |
| OTHER LYMPHOMA | 6 | 1.25 | 7 | 0.85 | 112 | 1.33 | 204 | 1.37 |
| MULTIPLE MYELOMA | 0 | 0.00 | 0 | 0.00 | 1 | 2.99 | 1 | 1.72 |
| DIGESTIVE ORGANS | 2 | 0.98 | 3 | 0.88 | 27 | 0.79 | 60 | 0.99 |
| STOMACH | 1 | 7.36 | 0 | 0.00 | 1 | 0.75 | 2 | 0.84 |
| COLON & RECTUM | 0 | 0.00 | 1 | 2.21 | 6 | 1.71 | 5 | 0.81 |
| LIVER (PRIMARY) | 0 | 0.00 | 1 | 0.57 | 14 | 0.65 | 40 | 1.05 |
| TRACHEA, BRONCHUS, LUNG | 0 | 0.00 | 2 | 3.81 | 14 | 2.34 | 8 | 0.76 |
| BREAST (FEMALE) | 0 | 0.00 | 0 | 0.00 | 3 | 2.80 | 2 | 1.06 |
| THYROID | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 1 | 1.11 |
| BONES & JOINTS | 1 | 0.76 | 1 | 0.45 | 13 | 0.56 | 43 | 1.04 |
| BLADDER | 0 | 0.00 | 1 | 2.38 | 6 | 1.81 | 7 | 1.19 |
| BRAIN & OTHER C.N.S. | 19 | 1.38 | 21 | 0.88 | 244 | 0.94 | 479 | 1.05 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 19 | 0.70 | 46 | 0.96 |

Table 1-A

Age at death: under 10 — Department of Energy facilities

| Disease | Relative Risks: Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.45 | 1.06 | 0.90 | 1.06 |
| ALL CANCER, EXCL LEUK | 1.06 | 0.95 | 1.13 | 0.90 |
| HODGKIN'S DISEASE | - | - | - | - |
| OTHER LYMPHOMA | - | 0.97 | - | 1.91 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | - | 0.70 | - | - |
| STOMACH | - | - | - | - |
| COLON & RECTUM | - | - | - | - |
| LIVER (PRIMARY) | - | 0.57 | - | - |
| TRACHEA, BRONCHUS, LUNG | - | 2.65* | - | - |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | - | 0.55 | - | - |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 1.34 | 0.90 | 0.69 | 0.90 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.68 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-A

Age at death: 10 to 19 — Department of Energy facilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 11 | 0.84 | 27 | 1.18 | 336 | 0.97 | 575 | 0.92 |
| ALL CANCER, EXCL LEUK | 22 | 0.86 | 36 | 0.81 | 683 | 1.05 | 1193 | 1.02 |
| HODGKIN'S DISEASE | 3 | 1.09 | 4 | 0.84 | 37 | 0.62 | 114 | 1.06 |
| OTHER LYMPHOMA | 2 | 0.58 | 4 | 0.65 | 105 | 1.11 | 187 | 1.10 |
| MULTIPLE MYELOMA | 0 | 0.00 | 0 | 0.00 | 1 | 2.37 | 1 | 1.28 |
| DIGESTIVE ORGANS | 1 | 0.64 | 2 | 0.78 | 34 | 1.06 | 50 | 0.87 |
| STOMACH | 0 | 0.00 | 0 | 0.00 | 3 | 1.42 | 3 | 0.79 |
| COLON & RECTUM | 0 | 0.00 | 1 | 0.87 | 13 | 1.11 | 21 | 0.99 |
| LIVER (PRIMARY) | 0 | 0.00 | 1 | 1.52 | 11 | 0.92 | 11 | 0.52 |
| TRACHEA, BRONCHUS, LUNG | 1 | 2.48 | 0 | 0.00 | 7 | 1.01 | 15 | 1.20 |
| BREAST (FEMALE) | 0 | 0.00 | 0 | 0.00 | 2 | 1.46 | 3 | 1.21 |
| THYROID | 0 | 0.00 | 0 | 0.00 | 2 | 1.27 | 1 | 0.35 |
| BONES & JOINTS | 7 | 1.46 | 10 | 1.21 | 144 | 1.20 | 191 | 0.89 |
| BLADDER | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| BRAIN & OTHER C.N.S. | 7 | 1.12 | 8 | 0.73 | 172 | 1.05 | 304 | 1.04 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 16 | 0.77 | 31 | 0.86 |

Table 1-A

Age at death: 10 to 19 — Department of Energy facilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 0.68 | 1.07 | 1.19 | 0.77 |
| ALL CANCER, EXCL LEUK | 1.07 | 1.04 | 1.22 | 1.24 |
| HODGKIN'S DISEASE | - | 0.56** | - | - |
| OTHER LYMPHOMA | - | 1.01 | - | - |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | - | 1.30 | - | - |
| STOMACH | - | - | - | - |
| COLON & RECTUM | - | 1.35 | - | - |
| LIVER (PRIMARY) | - | 1.74 | - | - |
| TRACHEA, BRONCHUS, LUNG | - | - | - | - |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | - | 1.34** | 1.08 | 0.59 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | - | 1.04 | - | 1.73 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.94 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-A

Age at death: 20 to 39 Department of Energy facilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 14 | 0.58 | 40 | 1.03 | 543 | 0.97 | 1001 | 1.01 |
| ALL CANCER, EXCL LEUK | 236 | 1.06 | 385 | 1.09 | 4922 | 1.04 | 8376 | 1.01 |
| HODGKIN'S DISEASE | 19 | 1.00 | 47 | 1.52 | 389 | 1.00 | 724 | 1.05 |
| OTHER LYMPHOMA | 20 | 1.74 | 16 | 0.86 | 302 | 1.07 | 501 | 1.01 |
| MULTIPLE MYELOMA | 2 | 2.15 | 3 | 2.03 | 22 | 1.05 | 30 | 0.83 |
| DIGESTIVE ORGANS | 41 | 0.99 | 69 | 1.07 | 748 | 0.98 | 1304 | 0.98 |
| STOMACH | 8 | 0.84 | 10 | 0.69 | 118 | 0.79 | 215 | 0.83 |
| COLON & RECTUM | 27 | 1.32 | 38 | 1.19 | 361 | 0.98 | 707 | 1.10 |
| LIVER (PRIMARY) | 3 | 0.68 | 6 | 0.88 | 103 | 1.28 | 128 | 0.92 |
| TRACHEA, BRONCHUS, LUNG | 8 | 0.62 | 24 | 1.12 | 415 | 1.05 | 728 | 1.06 |
| BREAST (FEMALE) | 32 | 1.06 | 47 | 1.00 | 731 | 1.07 | 1086 | 0.92 |
| THYROID | 2 | 2.62 | 0 | 0.00 | 13 | 0.90 | 29 | 1.15 |
| BONES & JOINTS | 6 | 1.34 | 7 | 1.00 | 118 | 1.31 | 153 | 0.95 |
| BLADDER | 0 | 0.00 | 3 | 1.61 | 19 | 1.03 | 39 | 1.23 |
| BRAIN & OTHER C.N.S. | 15 | 0.81 | 28 | 0.93 | 459 | 1.08 | 796 | 1.07 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 40 | 0.72 | 95 | 0.98 |

Table 1-A

Age at death: 20 to 39 — Department of Energy facilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 0.54 | 0.97 | 1.73* | 0.98 |
| ALL CANCER, EXCL LEUK | 0.95 | 1.03 | 1.02 | 0.93 |
| HODGKIN'S DISEASE | 0.61 | 0.94 | 1.07 | 0.63** |
| OTHER LYMPHOMA | 1.83 | 1.05 | 0.47** | 1.37 |
| MULTIPLE MYELOMA | - | 1.48 | - | - |
| DIGESTIVE ORGANS | 1.02 | 1.00 | 1.14 | 1.01 |
| STOMACH | - | 0.95 | 0.92 | 1.30 |
| COLON & RECTUM | 1.20 | 0.89 | 0.90 | 0.98 |
| LIVER (PRIMARY) | - | 1.37* | - | 1.11 |
| TRACHEA, BRONCHUS, LUNG | 0.54 | 1.00 | 1.65 | 1.11 |
| BREAST (FEMALE) | 1.10 | 1.15** | 1.21 | 0.88 |
| THYROID | - | 0.73 | - | - |
| BONES & JOINTS | - | 1.37* | - | 0.81 |
| BLADDER | - | 0.73 | - | - |
| BRAIN & OTHER C.N.S. | 0.80 | 1.04 | 1.22 | 0.93 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.73 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-A

Age at death: 40 to 59 — Department of Energy facilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 63 | 1.13 | 71 | 0.80 | 1187 | 1.00 | 2186 | 1.03 |
| ALL CANCER, EXCL LEUK | 1621 | 1.07 | 2342 | 0.98 | 38594 | 1.06 | 64666 | 1.00 |
| HODGKIN'S DISEASE | 21 | 0.97 | 30 | 0.87 | 370 | 0.94 | 712 | 1.01 |
| OTHER LYMPHOMA | 50 | 1.23 | 73 | 1.10 | 1102 | 1.01 | 1992 | 1.02 |
| MULTIPLE MYELOMA | 19 | 1.29 | 19 | 0.80 | 485 | 1.12 | 777 | 1.02 |
| DIGESTIVE ORGANS | 477 | 1.02 | 740 | 1.03 | 9193 | 1.02 | 15556 | 0.97 |
| STOMACH | 81 | 0.72 | 158 | 0.95 | 1289 | 0.82 | 2610 | 0.94 |
| COLON & RECTUM | 218 | 1.13 | 342 | 1.14 | 4211 | 1.09 | 6612 | 0.96 |
| LIVER (PRIMARY) | 64 | 1.13 | 82 | 0.96 | 792 | 1.02 | 1360 | 0.99 |
| TRACHEA, BRONCHUS, LUNG | 209 | 0.94 | 349 | 0.94 | 10072 | 1.16 | 16308 | 1.06 |
| BREAST (FEMALE) | 242 | 1.19 | 296 | 0.93 | 5303 | 1.06 | 8620 | 0.97 |
| THYROID | 6 | 0.96 | 6 | 0.63 | 121 | 1.20 | 192 | 1.06 |
| BONES & JOINTS | 6 | 0.51 | 19 | 1.07 | 160 | 0.96 | 288 | 0.97 |
| BLADDER | 31 | 1.09 | 48 | 1.10 | 495 | 1.01 | 891 | 1.02 |
| BRAIN & OTHER C.N.S. | 53 | 1.00 | 75 | 0.87 | 1301 | 1.01 | 2366 | 1.02 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 176 | 0.95 | 295 | 0.92 |

Table 1-A

Age at death: 40 to 59 — Department of Energy facilities

| Disease | Relative Risks: Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.39 | 0.97 | 0.91 | 1.23 |
| ALL CANCER, EXCL LEUK | 1.07 | 1.04*** | 1.03 | 1.03 |
| HODGKIN'S DISEASE | 1.05 | 0.91 | 0.98 | 1.12 |
| OTHER LYMPHOMA | 1.18 | 0.98 | 0.88 | 0.91 |
| MULTIPLE MYELOMA | 1.55 | 1.09 | 0.79 | 1.10 |
| DIGESTIVE ORGANS | 0.96 | 1.02 | 1.07 | 0.95 |
| STOMACH | 0.83 | 0.88*** | 1.21 | 1.00 |
| COLON & RECTUM | 0.95 | 1.09*** | 1.12 | 0.90 |
| LIVER (PRIMARY) | 1.06 | 1.02 | 0.87 | 1.00 |
| TRACHEA, BRONCHUS, LUNG | 0.93 | 1.08*** | 1.17* | 1.17** |
| BREAST (FEMALE) | 1.35*** | 1.07*** | 0.97 | 1.12 |
| THYROID | - | 1.11 | 1.19 | 1.75 |
| BONES & JOINTS | 0.48 | 0.96 | 1.56 | 0.77 |
| BLADDER | 0.86 | 0.97 | 0.91 | 0.90 |
| BRAIN & OTHER C.N.S. | 1.14 | 1.00 | 1.01 | 1.08 |
| BENIGN & UNSPEC NEOPLASMS | - | 1.03 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-A

Age at death: 60 plus — Department of Energy facilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 131 | 1.02 | 215 | 0.94 | 3410 | 1.00 | 6886 | 1.05 |
| ALL CANCER, EXCL LEUK | 3864 | 1.03 | 6172 | 0.95 | 96776 | 1.06 | 171840 | 0.99 |
| HODGKIN'S DISEASE | 20 | 0.84 | 52 | 1.27 | 385 | 0.87 | 849 | 1.00 |
| OTHER LYMPHOMA | 85 | 1.20 | 119 | 0.93 | 2487 | 1.02 | 4713 | 1.01 |
| MULTIPLE MYELOMA | 35 | 1.15 | 58 | 1.04 | 1431 | 1.06 | 2714 | 1.07 |
| DIGESTIVE ORGANS | 1613 | 0.99 | 2597 | 0.93 | 33051 | 1.03 | 59440 | 0.97 |
| STOMACH | 416 | 0.94 | 569 | 0.78 | 4796 | 0.81 | 10041 | 0.89 |
| COLON & RECTUM | 727 | 1.07 | 1199 | 1.02 | 16804 | 1.13 | 28083 | 0.99 |
| LIVER (PRIMARY) | 190 | 0.97 | 356 | 1.08 | 2709 | 1.06 | 4768 | 0.98 |
| TRACHEA, BRONCHUS, LUNG | 369 | 0.94 | 631 | 0.86 | 20265 | 1.14 | 34511 | 1.02 |
| BREAST (FEMALE) | 334 | 1.17 | 491 | 1.04 | 7761 | 1.10 | 12817 | 0.97 |
| THYROID | 20 | 1.17 | 31 | 1.07 | 335 | 1.05 | 631 | 1.05 |
| BONES & JOINTS | 26 | 0.95 | 44 | 0.97 | 370 | 0.99 | 715 | 0.99 |
| BLADDER | 151 | 1.04 | 256 | 1.01 | 3329 | 1.09 | 5857 | 0.99 |
| BRAIN & OTHER C.N.S. | 38 | 1.23 | 50 | 0.90 | 1409 | 1.04 | 2580 | 1.00 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 377 | 0.89 | 744 | 0.94 |

Table 1-A

Age at death: 60 plus — Department of Energy facilities

| Disease | Relative Risks: Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.02 | 0.94** | 0.95 | 1.16 |
| ALL CANCER, EXCL LEUK | 1.06** | 1.04*** | 1.06** | 1.04** |
| HODGKIN'S DISEASE | 0.69 | 0.84** | 1.09 | 0.82 |
| OTHER LYMPHOMA | 1.25 | 1.00 | 0.81 | 1.14 |
| MULTIPLE MYELOMA | 1.01 | 0.99 | 0.98 | 1.02 |
| DIGESTIVE ORGANS | 1.04 | 1.02** | 1.10*** | 1.05* |
| STOMACH | 1.22** | 0.93*** | 0.98 | 1.00 |
| COLON & RECTUM | 1.02 | 1.08*** | 1.12** | 1.04 |
| LIVER (PRIMARY) | 0.82* | 1.04 | 0.94 | 0.82** |
| TRACHEA, BRONCHUS, LUNG | 1.08 | 1.09*** | 1.19** | 1.20*** |
| BREAST (FEMALE) | 1.11 | 1.08*** | 0.98 | 1.03 |
| THYROID | 1.08 | 0.97 | 0.74 | 1.06 |
| BONES & JOINTS | 0.99 | 0.99 | 1.24 | 0.99 |
| BLADDER | 1.04 | 1.06* | 1.12 | 1.12 |
| BRAIN & OTHER C.N.S. | 1.28 | 1.01 | 0.74 | 0.92 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.92 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-A

Age at death: all — Department of Energy facilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 258 | 1.01 | 401 | 0.92 | 6077 | 1.00 | 11657 | 1.03 |
| ALL CANCER, EXCL LEUK | 5780 | 1.04 | 8991 | 0.96 | 141635 | 1.06 | 247308 | 0.99 |
| HODGKIN'S DISEASE | 64 | 0.94 | 135 | 1.20 | 1186 | 0.92 | 2408 | 1.02 |
| OTHER LYMPHOMA | 163 | 1.24 | 219 | 0.96 | 4108 | 1.03 | 7597 | 1.02 |
| MULTIPLE MYELOMA | 56 | 1.21 | 80 | 0.98 | 1940 | 1.07 | 3523 | 1.06 |
| DIGESTIVE ORGANS | 2134 | 0.99 | 3411 | 0.95 | 43053 | 1.03 | 76410 | 0.97 |
| STOMACH | 506 | 0.90 | 737 | 0.81 | 6207 | 0.82 | 12871 | 0.90 |
| COLON & RECTUM | 972 | 1.09 | 1581 | 1.05 | 21395 | 1.12 | 35428 | 0.98 |
| LIVER (PRIMARY) | 257 | 0.99 | 446 | 1.05 | 3629 | 1.06 | 6307 | 0.98 |
| TRACHEA, BRONCHUS, LUNG | 587 | 0.94 | 1006 | 0.89 | 30773 | 1.15 | 51570 | 1.03 |
| BREAST (FEMALE) | 608 | 1.17 | 834 | 0.99 | 13800 | 1.08 | 22528 | 0.97 |
| THYROID | 28 | 1.15 | 37 | 0.93 | 471 | 1.08 | 854 | 1.05 |
| BONES & JOINTS | 46 | 0.93 | 81 | 1.00 | 805 | 1.04 | 1390 | 0.97 |
| BLADDER | 182 | 1.04 | 308 | 1.03 | 3849 | 1.08 | 6794 | 0.99 |
| BRAIN & OTHER C.N.S. | 132 | 1.08 | 182 | 0.88 | 3585 | 1.03 | 6525 | 1.02 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 628 | 0.88 | 1211 | 0.94 |

Table 1-A

Age at death: all — Department of Energy facilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.07 | 0.96* | 0.99 | 1.12 |
| ALL CANCER, EXCL LEUK | 1.06** | 1.04*** | 1.05** | 1.04** |
| HODGKIN'S DISEASE | 0.76 | 0.88*** | 1.00 | 0.82 |
| OTHER LYMPHOMA | 1.27* | 0.99 | 0.80* | 1.11 |
| MULTIPLE MYELOMA | 1.13 | 1.02 | 0.89 | 1.03 |
| DIGESTIVE ORGANS | 1.02 | 1.02*** | 1.09*** | 1.03 |
| STOMACH | 1.15* | 0.92*** | 1.02 | 1.01 |
| COLON & RECTUM | 1.00 | 1.07*** | 1.12** | 1.01 |
| LIVER (PRIMARY) | 0.86 | 1.04 | 0.94 | 0.86* |
| TRACHEA, BRONCHUS, LUNG | 1.01 | 1.09*** | 1.19*** | 1.18*** |
| BREAST (FEMALE) | 1.19** | 1.08*** | 0.99 | 1.05 |
| THYROID | 1.25 | 0.99 | 0.82 | 1.21 |
| BONES & JOINTS | 0.93 | 1.06 | 1.20 | 0.86 |
| BLADDER | 1.00 | 1.05* | 1.09 | 1.07 |
| BRAIN & OTHER C.N.S. | 1.17 | 1.00 | 0.91 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.92 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B,C,D

Age at death: under 10 — All Electric Utilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 1981 | 1.07 | 4203 | 0.99 | 789 | 1.01 | 1563 | 0.98 |
| ALL CANCER, EXCL LEUK | 1932 | 0.99 | 4567 | 1.03 | 1057 | 1.06 | 2010 | 1.01 |
| HODGKIN'S DISEASE | 41 | 1.32 | 67 | 0.94 | 8 | 0.96 | 17 | 0.99 |
| OTHER LYMPHOMA | 260 | 0.99 | 577 | 0.96 | 105 | 0.97 | 193 | 0.88 |
| MULTIPLE MYELOMA | 1 | 1.17 | 3 | 1.56 | 3 | 5.13 | 1 | 0.88 |
| DIGESTIVE ORGANS | 95 | 0.95 | 237 | 1.03 | 68 | 1.32 | 100 | 0.98 |
| STOMACH | 2 | 0.45 | 10 | 0.97 | 4 | 3.10 | 2 | 0.78 |
| COLON & RECTUM | 15 | 1.35 | 25 | 0.98 | 10 | 2.38 | 13 | 1.57 |
| LIVER (PRIMARY) | 59 | 1.01 | 140 | 1.05 | 43 | 1.14 | 73 | 0.98 |
| TRACHEA, BRONCHUS, LUNG | 13 | 0.80 | 42 | 1.14 | 12 | 1.14 | 11 | 0.54 |
| BREAST (FEMALE) | 2 | 0.77 | 14 | 2.38 | 2 | 0.94 | 2 | 0.48 |
| THYROID | 2 | 1.06 | 5 | 1.13 | 0 | 0.00 | 1 | 1.32 |
| BONES & JOINTS | 73 | 1.04 | 172 | 1.07 | 33 | 0.99 | 68 | 1.01 |
| BLADDER | 13 | 1.16 | 26 | 1.01 | 3 | 0.87 | 6 | 0.86 |
| BRAIN & OTHER C.N.S. | 789 | 1.01 | 1832 | 1.03 | 381 | 1.05 | 729 | 0.99 |
| BENIGN & UNSPEC NEOPLASMS | 47 | 1.28 | 80 | 0.97 | 85 | 0.97 | 146 | 0.89 |

Table 1-B,C,D

Age at death: under 10 — All Electric Utilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.08* | 1.01 | 0.93 | 0.95 |
| ALL CANCER, EXCL LEUK | 0.94* | 1.01 | 1.05 | 0.96 |
| HODGKIN'S DISEASE | 1.43 | 0.80 | - | 1.10 |
| OTHER LYMPHOMA | 0.93 | 1.03 | 0.92 | 0.91 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.93 | 1.26 | 1.25 | 0.91 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | 1.79 | 1.37 | - | 1.64 |
| LIVER (PRIMARY) | 0.92 | 1.16 | 0.97 | 0.87 |
| TRACHEA, BRONCHUS, LUNG | 0.72 | - | - | 0.42* |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 1.04 | 0.94 | 0.95 | 0.96 |
| BLADDER | 1.25 | - | - | - |
| BRAIN & OTHER C.N.S. | 0.96 | 1.06 | 1.01 | 0.95 |
| BENIGN & UNSPEC NEOPLASMS | 1.39 | 1.14 | 0.75 | 0.92 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B,C,D

Age at death: 10 to 19 — All Electric Utilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 912 | 1.01 | 2008 | 0.98 | 660 | 0.94 | 1488 | 1.06 |
| ALL CANCER, EXCL LEUK | 1662 | 0.96 | 3804 | 0.97 | 1280 | 1.00 | 2478 | 0.97 |
| HODGKIN'S DISEASE | 167 | 0.94 | 389 | 0.97 | 78 | 0.82 | 222 | 1.15 |
| OTHER LYMPHOMA | 261 | 1.03 | 541 | 0.95 | 181 | 0.97 | 360 | 0.97 |
| MULTIPLE MYELOMA | 1 | 0.94 | 0 | 0.00 | 2 | 2.13 | 4 | 2.17 |
| DIGESTIVE ORGANS | 76 | 0.88 | 208 | 1.07 | 71 | 1.16 | 100 | 0.83 |
| STOMACH | 1 | 0.16 | 7 | 0.49 | 6 | 1.84 | 3 | 0.48 |
| COLON & RECTUM | 27 | 0.81 | 81 | 1.08 | 19 | 0.93 | 26 | 0.66 |
| LIVER (PRIMARY) | 29 | 1.03 | 74 | 1.17 | 34 | 1.30 | 53 | 1.03 |
| TRACHEA, BRONCHUS, LUNG | 15 | 0.76 | 40 | 0.88 | 15 | 1.22 | 26 | 1.07 |
| BREAST (FEMALE) | 1 | 0.27 | 7 | 0.82 | 3 | 1.22 | 1 | 0.20 |
| THYROID | 2 | 0.43 | 12 | 1.13 | 1 | 0.40 | 8 | 1.56 |
| BONES & JOINTS | 287 | 0.90 | 716 | 0.99 | 218 | 0.93 | 449 | 0.96 |
| BLADDER | 0 | 0.00 | 5 | 1.40 | 0 | 0.00 | 1 | 0.56 |
| BRAIN & OTHER C.N.S. | 422 | 0.99 | 909 | 0.93 | 339 | 1.04 | 615 | 0.94 |
| BENIGN & UNSPEC NEOPLASMS | 36 | 1.19 | 67 | 0.96 | 59 | 0.90 | 136 | 1.09 |

Table 1-B,C,D

Age at death: 10 to 19 — All Electric Utilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.03 | 0.88* | 0.92 | 1.05 |
| ALL CANCER, EXCL LEUK | 0.98 | 1.03 | 1.03 | 0.96 |
| HODGKIN'S DISEASE | 1.01 | 0.78 | 0.85 | 1.07 |
| OTHER LYMPHOMA | 1.12 | 0.99 | 0.93 | 0.96 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.85 | 1.30 | 1.40 | 0.76* |
| STOMACH | - | - | - | - |
| COLON & RECTUM | 0.71 | 1.38 | 1.26 | 0.59* |
| LIVER (PRIMARY) | 0.93 | 1.31 | 1.28 | 0.83 |
| TRACHEA, BRONCHUS, LUNG | 0.85 | 1.19 | 1.59 | 1.28 |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 0.91 | 0.99 | 1.03 | 0.96 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 1.01 | 1.05 | 1.06 | 0.99 |
| BENIGN & UNSPEC NEOPLASMS | 1.30 | 0.79 | 0.70 | 1.12 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B,C,D

Age at death: 20 to 39 — All Electric Utilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 1377 | 0.99 | 2899 | 0.93 | 1291 | 1.03 | 2394 | 1.03 |
| ALL CANCER, EXCL LEUK | 12065 | 0.97 | 27496 | 0.99 | 9424 | 0.97 | 18477 | 1.01 |
| HODGKIN'S DISEASE | 1132 | 1.02 | 2578 | 1.04 | 732 | 1.04 | 1506 | 1.13 |
| OTHER LYMPHOMA | 662 | 0.96 | 1540 | 1.00 | 672 | 1.05 | 1234 | 1.03 |
| MULTIPLE MYELOMA | 58 | 1.07 | 132 | 1.09 | 49 | 1.15 | 96 | 1.21 |
| DIGESTIVE ORGANS | 1963 | 0.93 | 4851 | 1.02 | 1328 | 0.92 | 2622 | 0.97 |
| STOMACH | 365 | 0.83 | 1002 | 1.01 | 227 | 0.93 | 411 | 0.90 |
| COLON & RECTUM | 970 | 0.94 | 2373 | 1.02 | 621 | 0.90 | 1272 | 0.97 |
| LIVER (PRIMARY) | 223 | 1.03 | 476 | 0.99 | 159 | 1.03 | 296 | 1.05 |
| TRACHEA, BRONCHUS, LUNG | 889 | 0.93 | 2086 | 0.99 | 878 | 0.97 | 1645 | 0.96 |
| BREAST (FEMALE) | 1682 | 0.98 | 3894 | 1.01 | 1424 | 0.98 | 2972 | 1.07 |
| THYROID | 38 | 0.93 | 93 | 1.01 | 31 | 1.22 | 55 | 1.13 |
| BONES & JOINTS | 245 | 1.07 | 496 | 0.97 | 214 | 1.08 | 357 | 0.98 |
| BLADDER | 63 | 1.18 | 114 | 0.95 | 33 | 1.07 | 67 | 1.14 |
| BRAIN & OTHER C.N.S. | 1036 | 0.96 | 2267 | 0.93 | 858 | 0.94 | 1656 | 0.96 |
| BENIGN & UNSPEC NEOPLASMS | 64 | 0.87 | 170 | 1.05 | 191 | 0.98 | 334 | 0.97 |

Table 1-B,C,D

Age at death: 20 to 39 — All Electric Utilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.06 | 1.03 | 1.04 | 1.10** |
| ALL CANCER, EXCL LEUK | 1.01 | 0.99 | 1.02 | 1.01 |
| HODGKIN'S DISEASE | 1.05 | 1.02 | 1.01 | 1.03 |
| OTHER LYMPHOMA | 0.99 | 1.07 | 1.09 | 0.96 |
| MULTIPLE MYELOMA | 0.99 | 1.05 | 1.03 | 1.07 |
| DIGESTIVE ORGANS | 0.95 | 0.97 | 1.00 | 0.94** |
| STOMACH | 0.84** | 0.98 | 1.11 | 0.86* |
| COLON & RECTUM | 0.98 | 0.97 | 0.96 | 0.95 |
| LIVER (PRIMARY) | 1.09 | 1.01 | 1.03 | 1.05 |
| TRACHEA, BRONCHUS, LUNG | 0.95 | 1.01 | 1.07 | 1.00 |
| BREAST (FEMALE) | 1.02 | 0.94 | 0.97 | 1.04 |
| THYROID | 0.90 | 1.15 | 1.31 | 1.13 |
| BONES & JOINTS | 1.16 | 1.21* | 1.10 | 1.00 |
| BLADDER | 1.39* | 0.85 | 0.87 | 1.28 |
| BRAIN & OTHER C.N.S. | 1.01 | 1.00 | 0.97 | 1.04 |
| BENIGN & UNSPEC NEOPLASMS | 0.84 | 1.07 | 1.21 | 0.87 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B,C,D

Age at death: 40 to 59 — All Electric Utilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 3099 | 0.98 | 7200 | 0.97 | 2605 | 1.01 | 5331 | 1.00 |
| ALL CANCER, EXCL LEUK | 89875 | 0.99 | 211918 | 1.00 | 81518 | 0.98 | 172196 | 1.01 |
| HODGKIN'S DISEASE | 1163 | 0.94 | 2949 | 1.02 | 646 | 0.99 | 1493 | 1.09 |
| OTHER LYMPHOMA | 2849 | 1.05 | 6147 | 0.97 | 2671 | 1.03 | 5556 | 1.03 |
| MULTIPLE MYELOMA | 1002 | 0.99 | 2298 | 0.98 | 974 | 0.95 | 1999 | 0.96 |
| DIGESTIVE ORGANS | 24022 | 0.98 | 58005 | 1.01 | 18319 | 0.99 | 39564 | 1.04 |
| STOMACH | 4408 | 0.92 | 11211 | 1.00 | 2554 | 1.00 | 5594 | 1.07 |
| COLON & RECTUM | 10631 | 1.02 | 25526 | 1.04 | 8168 | 1.00 | 18325 | 1.08 |
| LIVER (PRIMARY) | 2378 | 0.95 | 5835 | 1.00 | 1048 | 0.92 | 2087 | 0.89 |
| TRACHEA, BRONCHUS, LUNG | 17608 | 0.99 | 40828 | 0.98 | 22874 | 0.95 | 46931 | 0.95 |
| BREAST (FEMALE) | 12622 | 1.00 | 29839 | 1.01 | 12024 | 1.04 | 25097 | 1.06 |
| THYROID | 254 | 0.85 | 761 | 1.08 | 182 | 0.99 | 386 | 1.01 |
| BONES & JOINTS | 506 | 0.96 | 1222 | 0.98 | 238 | 0.90 | 517 | 0.94 |
| BLADDER | 1454 | 1.04 | 3497 | 1.07 | 972 | 1.04 | 2100 | 1.08 |
| BRAIN & OTHER C.N.S. | 3351 | 1.01 | 7705 | 0.99 | 2841 | 0.95 | 6089 | 0.98 |
| BENIGN & UNSPEC NEOPLASMS | 259 | 1.01 | 724 | 1.20 | 588 | 0.93 | 1227 | 0.99 |

Table 1-B,C,D

Age at death: 40 to 59 — All Electric Utilities

| Disease | Relative Risks: Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.00 | 1.02 | 1.03 | 1.02 |
| ALL CANCER, EXCL LEUK | 1.00 | 0.99 | 0.98*** | 0.99 |
| HODGKIN'S DISEASE | 0.97 | 1.00 | 1.07 | 1.06 |
| OTHER LYMPHOMA | 1.10*** | 1.01 | 0.95 | 1.04* |
| MULTIPLE MYELOMA | 1.00 | 1.02 | 0.96 | 0.97 |
| DIGESTIVE ORGANS | 1.01 | 1.00 | 1.00 | 1.00 |
| STOMACH | 0.96* | 0.97 | 1.03 | 1.02 |
| COLON & RECTUM | 1.05*** | 0.99 | 0.97 | 1.01 |
| LIVER (PRIMARY) | 0.98 | 1.04 | 0.97 | 0.88*** |
| TRACHEA, BRONCHUS, LUNG | 1.00 | 0.99 | 0.96*** | 0.99 |
| BREAST (FEMALE) | 1.01 | 1.02 | 1.01 | 1.01 |
| THYROID | 0.83* | 1.07 | 1.13 | 0.89 |
| BONES & JOINTS | 1.02 | 1.00 | 1.01 | 0.98 |
| BLADDER | 0.98 | 0.99 | 1.00 | 0.98 |
| BRAIN & OTHER C.N.S. | 1.01 | 0.94** | 0.95 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | 0.89 | 0.98 | 0.91 | 0.79*** |

*  : 0.01 < P <= 0.05
**  : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B,C,D

Age at death: 60 plus — All Electric Utilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 8380 | 0.97 | 19260 | 0.96 | 9754 | 0.97 | 20141 | 1.00 |
| ALL CANCER, EXCL LEUK | 222886 | 0.98 | 539734 | 1.02 | 269379 | 1.02 | 555505 | 1.05 |
| HODGKIN'S DISEASE | 1274 | 0.92 | 3460 | 1.07 | 1028 | 1.03 | 2066 | 1.02 |
| OTHER LYMPHOMA | 5813 | 1.07 | 12222 | 0.97 | 8436 | 1.05 | 16123 | 1.00 |
| MULTIPLE MYELOMA | 2726 | 1.00 | 6292 | 1.00 | 4480 | 1.00 | 9011 | 1.02 |
| DIGESTIVE ORGANS | 85514 | 0.96 | 213825 | 1.03 | 85215 | 1.03 | 178208 | 1.07 |
| STOMACH | 17859 | 0.92 | 47299 | 1.04 | 12016 | 1.05 | 25765 | 1.11 |
| COLON & RECTUM | 39428 | 1.00 | 97226 | 1.06 | 42838 | 1.04 | 89556 | 1.09 |
| LIVER (PRIMARY) | 8256 | 0.93 | 21088 | 1.01 | 4136 | 0.94 | 8820 | 0.97 |
| TRACHEA, BRONCHUS, LUNG | 34534 | 0.99 | 79849 | 0.99 | 63194 | 1.00 | 127583 | 1.01 |
| BREAST (FEMALE) | 16928 | 0.99 | 40465 | 1.02 | 21478 | 1.06 | 44392 | 1.09 |
| THYROID | 882 | 0.96 | 2112 | 0.98 | 792 | 1.04 | 1582 | 1.03 |
| BONES & JOINTS | 1192 | 0.95 | 3033 | 1.02 | 709 | 0.95 | 1440 | 0.96 |
| BLADDER | 8872 | 1.06 | 21357 | 1.09 | 8895 | 1.06 | 18330 | 1.10 |
| BRAIN & OTHER C.N.S. | 2720 | 1.04 | 5743 | 0.94 | 4966 | 1.02 | 9937 | 1.02 |
| BENIGN & UNSPEC NEOPLASMS | 543 | 1.01 | 1265 | 1.00 | 1852 | 1.04 | 3903 | 1.14 |

Table 1-B,C,D

Age at death: 60 plus — All Electric Utilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.00 | 0.98 | 0.99 | 1.04** |
| ALL CANCER, EXCL LEUK | 0.99 | 1.00 | 1.02*** | 1.01 |
| HODGKIN'S DISEASE | 0.88*** | 1.02 | 1.16** | 0.96 |
| OTHER LYMPHOMA | 1.09*** | 1.05*** | 0.97 | 1.03* |
| MULTIPLE MYELOMA | 0.98 | 0.98 | 1.01 | 1.02 |
| DIGESTIVE ORGANS | 0.98*** | 1.01 | 1.04*** | 1.01 |
| STOMACH | 0.94*** | 0.99 | 1.08*** | 1.03*** |
| COLON & RECTUM | 1.01 | 1.02*** | 1.03*** | 1.00 |
| LIVER (PRIMARY) | 0.95*** | 0.99 | 1.00 | 0.95*** |
| TRACHEA, BRONCHUS, LUNG | 1.00 | 0.99 | 0.99 | 1.01 |
| BREAST (FEMALE) | 1.00 | 1.01 | 1.04*** | 1.03*** |
| THYROID | 1.00 | 1.05 | 1.05 | 1.02 |
| BONES & JOINTS | 0.99 | 1.05 | 1.01 | 0.96 |
| BLADDER | 1.01 | 1.01 | 0.98 | 0.98* |
| BRAIN & OTHER C.N.S. | 1.06* | 0.98 | 0.96 | 1.09*** |
| BENIGN & UNSPEC NEOPLASMS | 1.03 | 0.95 | 1.01 | 1.05 |

*  : 0.01 < P <= 0.05
**  : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B,C,D

Age at death: all — All Electric Utilities

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 15749 | 0.99 | 35570 | 0.97 | 15099 | 0.98 | 30917 | 1.00 |
| ALL CANCER, EXCL LEUK | 328420 | 0.98 | 787519 | 1.01 | 362658 | 1.01 | 750666 | 1.04 |
| HODGKIN'S DISEASE | 3777 | 0.96 | 9443 | 1.04 | 2492 | 1.01 | 5304 | 1.07 |
| OTHER LYMPHOMA | 9845 | 1.05 | 21027 | 0.97 | 12065 | 1.04 | 23466 | 1.01 |
| MULTIPLE MYELOMA | 3788 | 1.00 | 8725 | 1.00 | 5508 | 0.99 | 11111 | 1.01 |
| DIGESTIVE ORGANS | 111670 | 0.97 | 277126 | 1.03 | 105001 | 1.02 | 220594 | 1.07 |
| STOMACH | 22635 | 0.92 | 59529 | 1.03 | 14807 | 1.04 | 31775 | 1.10 |
| COLON & RECTUM | 51071 | 1.00 | 125231 | 1.05 | 51656 | 1.03 | 109192 | 1.09 |
| LIVER (PRIMARY) | 10945 | 0.93 | 27613 | 1.01 | 5420 | 0.94 | 11329 | 0.96 |
| TRACHEA, BRONCHUS, LUNG | 53059 | 0.99 | 122845 | 0.99 | 86973 | 0.99 | 176196 | 1.00 |
| BREAST (FEMALE) | 31235 | 0.99 | 74219 | 1.02 | 34931 | 1.05 | 72464 | 1.08 |
| THYROID | 1178 | 0.93 | 2983 | 1.01 | 1006 | 1.03 | 2032 | 1.03 |
| BONES & JOINTS | 2303 | 0.96 | 5639 | 1.01 | 1412 | 0.96 | 2831 | 0.96 |
| BLADDER | 10402 | 1.06 | 24999 | 1.09 | 9903 | 1.06 | 20504 | 1.10 |
| BRAIN & OTHER C.N.S. | 8318 | 1.01 | 18456 | 0.97 | 9385 | 0.99 | 19026 | 1.00 |
| BENIGN & UNSPEC NEOPLASMS | 949 | 1.02 | 2306 | 1.05 | 2775 | 1.01 | 5746 | 1.08 |

Table 1-B,C,D

Age at death: all

All Electric Utilities

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.02 | 0.99 | 0.99 | 1.03*** |
| ALL CANCER, EXCL LEUK | 0.99 | 0.99 | 1.01 | 1.01 |
| HODGKIN'S DISEASE | 0.96* | 1.00 | 1.07* | 1.01 |
| OTHER LYMPHOMA | 1.08*** | 1.04*** | 0.97* | 1.03* |
| MULTIPLE MYELOMA | 0.98 | 0.99 | 1.00 | 1.01 |
| DIGESTIVE ORGANS | 0.99 | 1.01 | 1.03*** | 1.01 |
| STOMACH | 0.94*** | 0.99 | 1.07*** | 1.03*** |
| COLON & RECTUM | 1.02*** | 1.02** | 1.02** | 1.00 |
| LIVER (PRIMARY) | 0.96*** | 1.00 | 0.99 | 0.94*** |
| TRACHEA, BRONCHUS, LUNG | 0.99 | 0.99 | 0.98** | 1.00 |
| BREAST (FEMALE) | 1.01 | 1.01 | 1.02** | 1.02*** |
| THYROID | 0.95 | 1.05 | 1.07 | 1.00 |
| BONES & JOINTS | 1.00 | 1.05 | 1.02 | 0.97 |
| BLADDER | 1.01 | 1.00 | 0.98 | 0.98* |
| BRAIN & OTHER C.N.S. | 1.02 | 0.97 | 0.96* | 1.04*** |
| BENIGN & UNSPEC NEOPLASMS | 0.99 | 0.97 | 0.97 | 0.97 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B

Age at death: under 10 Electric Utilities < 1970

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 593 | 1.09 | 1035 | 1.05 | 534 | 1.03 | 993 | 1.00 |
| ALL CANCER, EXCL LEUK | 600 | 1.07 | 1038 | 1.02 | 654 | 1.07 | 1200 | 1.05 |
| HODGKIN'S DISEASE | 5 | 0.55 | 14 | 0.81 | 7 | 1.15 | 15 | 1.24 |
| OTHER LYMPHOMA | 82 | 1.05 | 143 | 1.00 | 73 | 1.04 | 114 | 0.85 |
| MULTIPLE MYELOMA | 1 | 3.79 | 0 | 0.00 | 0 | 0.00 | 1 | 2.03 |
| DIGESTIVE ORGANS | 36 | 1.22 | 62 | 1.15 | 45 | 1.46 | 59 | 1.05 |
| STOMACH | 1 | 0.72 | 3 | 1.11 | 1 | 1.36 | 1 | 0.75 |
| COLON & RECTUM | 2 | 0.58 | 8 | 1.22 | 8 | 3.27 | 7 | 1.57 |
| LIVER (PRIMARY) | 25 | 1.50 | 35 | 1.17 | 27 | 1.21 | 40 | 1.00 |
| TRACHEA, BRONCHUS, LUNG | 2 | 0.44 | 12 | 1.42 | 9 | 1.49 | 8 | 0.76 |
| BREAST (FEMALE) | 0 | 0.00 | 2 | 1.29 | 2 | 1.94 | 1 | 0.58 |
| THYROID | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 1 | 1.78 |
| BONES & JOINTS | 22 | 1.08 | 37 | 0.99 | 17 | 0.81 | 42 | 1.05 |
| BLADDER | 3 | 0.89 | 6 | 0.95 | 0 | 0.00 | 3 | 0.65 |
| BRAIN & OTHER C.N.S. | 256 | 1.12 | 415 | 1.00 | 239 | 1.05 | 445 | 1.03 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 51 | 0.99 | 72 | 0.87 |

Table 1-B

Age at death: under 10 Electric Utilities < 1970

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.03 | 1.00 | 0.95 | 0.95 |
| ALL CANCER, EXCL LEUK | 0.99 | 0.96 | 1.00 | 1.02 |
| HODGKIN'S DISEASE | - | 0.76 | - | 1.65 |
| OTHER LYMPHOMA | 0.90 | 1.12 | 0.98 | 0.86 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 1.20 | 1.27 | 1.20 | 0.86 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | - | - | - | - |
| LIVER (PRIMARY) | 1.50 | 1.27 | 0.81 | 0.75 |
| TRACHEA, BRONCHUS, LUNG | - | - | - | - |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 1.16 | 0.73 | 0.70 | 1.05 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 1.10 | 1.01 | 0.93 | 1.03 |
| BENIGN & UNSPEC NEOPLASMS | - | 1.17 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B

Age at death: 10 to 19 — Electric Utilities < 1970

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 247 | 1.07 | 394 | 1.00 | 397 | 0.94 | 825 | 1.08 |
| ALL CANCER, EXCL LEUK | 410 | 0.93 | 731 | 0.98 | 797 | 1.02 | 1454 | 1.03 |
| HODGKIN'S DISEASE | 41 | 0.83 | 93 | 1.14 | 50 | 0.81 | 154 | 1.33 |
| OTHER LYMPHOMA | 62 | 0.95 | 114 | 1.05 | 116 | 1.02 | 216 | 1.04 |
| MULTIPLE MYELOMA | 1 | 3.33 | 0 | 0.00 | 1 | 2.08 | 1 | 1.27 |
| DIGESTIVE ORGANS | 12 | 0.54 | 38 | 1.01 | 44 | 1.23 | 58 | 0.92 |
| STOMACH | 0 | 0.00 | 1 | 0.35 | 4 | 2.04 | 2 | 0.58 |
| COLON & RECTUM | 5 | 0.56 | 12 | 0.78 | 10 | 0.85 | 17 | 0.84 |
| LIVER (PRIMARY) | 6 | 0.88 | 15 | 1.33 | 20 | 1.34 | 29 | 1.10 |
| TRACHEA, BRONCHUS, LUNG | 4 | 0.77 | 4 | 0.44 | 10 | 1.31 | 18 | 1.32 |
| BREAST (FEMALE) | 0 | 0.00 | 1 | 0.59 | 2 | 1.36 | 1 | 0.38 |
| THYROID | 0 | 0.00 | 1 | 0.45 | 1 | 0.64 | 4 | 1.36 |
| BONES & JOINTS | 78 | 0.94 | 121 | 0.87 | 139 | 0.97 | 265 | 1.02 |
| BLADDER | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| BRAIN & OTHER C.N.S. | 101 | 0.92 | 173 | 0.92 | 205 | 1.04 | 359 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 36 | 0.90 | 81 | 1.23 |

Table 1-B

Age at death: 10 to 19 — Electric Utilities < 1970

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.11 | 0.88* | 0.89 | 1.07 |
| ALL CANCER, EXCL LEUK | 0.94 | 0.99 | 1.10 | 1.04 |
| HODGKIN'S DISEASE | 0.87 | 0.68* | 0.90 | 1.22 |
| OTHER LYMPHOMA | 1.01 | 0.95 | 1.08 | 0.97 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.68 | 1.19 | 2.30** | 0.87 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | - | - | - | 0.97 |
| LIVER (PRIMARY) | - | 1.26 | 1.42 | 0.78 |
| TRACHEA, BRONCHUS, LUNG | - | - | - | - |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 1.10 | 0.96 | 1.00 | 1.13 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 0.91 | 0.96 | 1.13 | 1.12 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.68 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B

Age at death: 20 to 39 Electric Utilities < 1970

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 400 | 1.04 | 618 | 0.93 | 736 | 1.02 | 1184 | 1.03 |
| ALL CANCER, EXCL LEUK | 3225 | 0.94 | 6040 | 1.00 | 5425 | 0.96 | 9569 | 1.03 |
| HODGKIN'S DISEASE | 324 | 1.03 | 594 | 1.11 | 456 | 1.03 | 913 | 1.24 |
| OTHER LYMPHOMA | 190 | 1.00 | 355 | 1.10 | 394 | 1.07 | 673 | 1.14 |
| MULTIPLE MYELOMA | 20 | 1.34 | 31 | 1.16 | 29 | 1.19 | 51 | 1.28 |
| DIGESTIVE ORGANS | 556 | 0.93 | 1140 | 1.05 | 769 | 0.91 | 1393 | 1.00 |
| STOMACH | 100 | 0.78 | 252 | 1.07 | 144 | 0.99 | 220 | 0.91 |
| COLON & RECTUM | 276 | 0.93 | 547 | 1.02 | 355 | 0.87 | 683 | 1.01 |
| LIVER (PRIMARY) | 62 | 1.03 | 110 | 1.02 | 83 | 0.94 | 150 | 1.07 |
| TRACHEA, BRONCHUS, LUNG | 216 | 0.89 | 405 | 0.97 | 492 | 0.93 | 808 | 0.92 |
| BREAST (FEMALE) | 494 | 1.06 | 924 | 1.09 | 820 | 0.99 | 1518 | 1.09 |
| THYROID | 10 | 0.86 | 17 | 0.82 | 18 | 1.16 | 27 | 1.03 |
| BONES & JOINTS | 56 | 0.87 | 114 | 1.05 | 118 | 1.03 | 185 | 1.04 |
| BLADDER | 18 | 1.18 | 25 | 0.89 | 23 | 1.25 | 32 | 1.03 |
| BRAIN & OTHER C.N.S. | 324 | 1.07 | 481 | 0.91 | 482 | 0.90 | 826 | 0.95 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 102 | 0.89 | 178 | 1.06 |

Table 1-B

Age at death: 20 to 39 — Electric Utilities < 1970

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.16* | 1.02 | 0.99 | 1.11* |
| ALL CANCER, EXCL LEUK | 1.01 | 0.97 | 1.02 | 1.03 |
| HODGKIN'S DISEASE | 1.09 | 0.99 | 1.00 | 1.11* |
| OTHER LYMPHOMA | 1.04 | 1.03 | 1.08 | 1.01 |
| MULTIPLE MYELOMA | 1.20 | 1.05 | 0.89 | 1.16 |
| DIGESTIVE ORGANS | 0.96 | 0.95 | 0.98 | 0.93 |
| STOMACH | 0.74* | 1.01 | 1.27 | 0.83* |
| COLON & RECTUM | 1.02 | 0.94 | 0.94 | 0.98 |
| LIVER (PRIMARY) | 1.18 | 0.89 | 0.93 | 1.02 |
| TRACHEA, BRONCHUS, LUNG | 0.95 | 1.01 | 1.06 | 0.97 |
| BREAST (FEMALE) | 1.10 | 0.95 | 0.92 | 0.99 |
| THYROID | - | 1.23 | 1.29 | 1.14 |
| BONES & JOINTS | 0.93 | 1.12 | 1.19 | 1.00 |
| BLADDER | 1.76 | 1.06 | 1.03 | 1.20 |
| BRAIN & OTHER C.N.S. | 1.16 | 0.99 | 0.85* | 1.05 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.90 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B

Age at death: 40 to 59 — Electric Utilities < 1970

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 822 | 1.00 | 1486 | 0.95 | 1511 | 1.01 | 2887 | 1.03 |
| ALL CANCER, EXCL LEUK | 21931 | 0.99 | 42690 | 1.03 | 46309 | 0.98 | 88826 | 1.01 |
| HODGKIN'S DISEASE | 296 | 0.90 | 625 | 1.00 | 406 | 0.96 | 926 | 1.10 |
| OTHER LYMPHOMA | 719 | 1.09 | 1274 | 1.03 | 1550 | 1.04 | 2967 | 1.06 |
| MULTIPLE MYELOMA | 229 | 0.97 | 431 | 0.98 | 546 | 0.97 | 996 | 0.96 |
| DIGESTIVE ORGANS | 6281 | 1.00 | 13038 | 1.09 | 10612 | 1.00 | 21289 | 1.06 |
| STOMACH | 1267 | 0.98 | 2754 | 1.09 | 1604 | 1.06 | 3206 | 1.11 |
| COLON & RECTUM | 2821 | 1.05 | 5896 | 1.15 | 4704 | 1.00 | 9886 | 1.10 |
| LIVER (PRIMARY) | 660 | 0.94 | 1312 | 0.96 | 602 | 0.88 | 1191 | 0.88 |
| TRACHEA, BRONCHUS, LUNG | 3773 | 0.99 | 6912 | 0.98 | 12619 | 0.96 | 22007 | 0.92 |
| BREAST (FEMALE) | 3349 | 1.08 | 6231 | 1.08 | 7096 | 1.08 | 13732 | 1.11 |
| THYROID | 71 | 0.87 | 179 | 1.14 | 111 | 1.02 | 238 | 1.14 |
| BONES & JOINTS | 117 | 0.80 | 252 | 0.89 | 133 | 0.81 | 303 | 0.95 |
| BLADDER | 401 | 1.11 | 801 | 1.14 | 559 | 1.02 | 1172 | 1.11 |
| BRAIN & OTHER C.N.S. | 833 | 1.00 | 1498 | 0.95 | 1623 | 0.94 | 3174 | 0.97 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 346 | 0.95 | 665 | 1.05 |

Table 1-B

Age at death: 40 to 59 — Electric Utilities < 1970

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.07 | 1.01 | 1.01 | 1.07* |
| ALL CANCER, EXCL LEUK | 1.01 | 1.01 | 0.99 | 0.97*** |
| HODGKIN'S DISEASE | 0.94 | 0.98 | 1.06 | 1.09 |
| OTHER LYMPHOMA | 1.10 | 1.01 | 0.95 | 1.01 |
| MULTIPLE MYELOMA | 1.01 | 1.05 | 1.00 | 0.96 |
| DIGESTIVE ORGANS | 1.00 | 1.01 | 1.00 | 0.96*** |
| STOMACH | 0.98 | 1.01 | 1.08* | 1.00 |
| COLON & RECTUM | 1.04 | 0.99 | 0.95* | 0.95** |
| LIVER (PRIMARY) | 1.02 | 0.99 | 0.92 | 0.88** |
| TRACHEA, BRONCHUS, LUNG | 1.04 | 1.05*** | 0.97 | 0.92*** |
| BREAST (FEMALE) | 1.03 | 1.03 | 1.00 | 1.01 |
| THYROID | 0.94 | 0.99 | 1.17 | 0.99 |
| BONES & JOINTS | 0.96 | 0.91 | 1.00 | 1.04 |
| BLADDER | 1.02 | 0.95 | 0.93 | 0.98 |
| BRAIN & OTHER C.N.S. | 1.02 | 0.92** | 0.93 | 1.03 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.94 | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B

Age at death: 60 plus — Electric Utilities < 1970

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 2026 | 1.01 | 3702 | 1.00 | 5300 | 0.99 | 9585 | 1.00 |
| ALL CANCER, EXCL LEUK | 53736 | 1.00 | 107246 | 1.07 | 143973 | 1.03 | 263626 | 1.07 |
| HODGKIN'S DISEASE | 296 | 0.85 | 658 | 1.01 | 582 | 1.00 | 1132 | 1.04 |
| OTHER LYMPHOMA | 1349 | 1.13 | 2223 | 1.03 | 4441 | 1.06 | 7323 | 1.00 |
| MULTIPLE MYELOMA | 615 | 1.12 | 1000 | 1.02 | 2248 | 0.99 | 4029 | 1.03 |
| DIGESTIVE ORGANS | 22156 | 1.00 | 46014 | 1.10 | 46969 | 1.05 | 89716 | 1.12 |
| STOMACH | 5132 | 0.97 | 11199 | 1.09 | 7050 | 1.09 | 13922 | 1.16 |
| COLON & RECTUM | 9919 | 1.03 | 20574 | 1.14 | 23363 | 1.06 | 44939 | 1.14 |
| LIVER (PRIMARY) | 2333 | 0.91 | 4978 | 1.02 | 2350 | 0.92 | 4869 | 0.99 |
| TRACHEA, BRONCHUS, LUNG | 7165 | 1.04 | 13301 | 1.07 | 32930 | 1.04 | 56280 | 1.02 |
| BREAST (FEMALE) | 4436 | 1.08 | 8379 | 1.11 | 11714 | 1.08 | 21354 | 1.12 |
| THYROID | 246 | 1.03 | 475 | 1.06 | 441 | 1.04 | 827 | 1.08 |
| BONES & JOINTS | 325 | 0.97 | 621 | 0.96 | 409 | 0.94 | 763 | 0.93 |
| BLADDER | 2259 | 1.11 | 4675 | 1.22 | 4879 | 1.09 | 9111 | 1.13 |
| BRAIN & OTHER C.N.S. | 567 | 1.08 | 936 | 0.98 | 2589 | 1.05 | 4326 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 977 | 1.06 | 1841 | 1.20 |

Table 1-B

Age at death: 60 plus — Electric Utilities < 1970

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.02 | 0.99 | 0.99 | 1.01 |
| ALL CANCER, EXCL LEUK | 0.99 | 1.01 | 1.02*** | 0.98*** |
| HODGKIN'S DISEASE | 0.83* | 0.97 | 1.16* | 1.03 |
| OTHER LYMPHOMA | 1.06 | 1.08*** | 0.94* | 0.96 |
| MULTIPLE MYELOMA | 1.09 | 0.95 | 0.89** | 1.01 |
| DIGESTIVE ORGANS | 0.99 | 1.02** | 1.04*** | 1.00 |
| STOMACH | 0.97 | 1.02 | 1.11*** | 1.03* |
| COLON & RECTUM | 1.01 | 1.02* | 1.02 | 0.98* |
| LIVER (PRIMARY) | 0.93** | 0.99 | 0.97 | 0.94** |
| TRACHEA, BRONCHUS, LUNG | 1.01 | 1.03*** | 0.99 | 0.94*** |
| BREAST (FEMALE) | 1.02 | 1.01 | 1.01 | 1.00 |
| THYROID | 1.01 | 1.04 | 1.00 | 0.99 |
| BONES & JOINTS | 1.19* | 1.10 | 0.97 | 0.95 |
| BLADDER | 0.99 | 1.03 | 0.97 | 0.92*** |
| BRAIN & OTHER C.N.S. | 1.08 | 1.03 | 0.97 | 1.02 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.92* | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-B

Age at death: all — Electric Utilities < 1970

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 4088 | 1.02 | 7235 | 0.99 | 8478 | 1.00 | 15474 | 1.01 |
| ALL CANCER, EXCL LEUK | 79902 | 1.00 | 157745 | 1.06 | 197158 | 1.02 | 364675 | 1.05 |
| HODGKIN'S DISEASE | 962 | 0.92 | 1984 | 1.04 | 1501 | 0.99 | 3140 | 1.12 |
| OTHER LYMPHOMA | 2402 | 1.10 | 4109 | 1.04 | 6574 | 1.06 | 11293 | 1.02 |
| MULTIPLE MYELOMA | 866 | 1.08 | 1462 | 1.01 | 2824 | 0.99 | 5078 | 1.02 |
| DIGESTIVE ORGANS | 29041 | 1.00 | 60292 | 1.10 | 58439 | 1.04 | 112515 | 1.11 |
| STOMACH | 6500 | 0.97 | 14209 | 1.09 | 8803 | 1.09 | 17351 | 1.15 |
| COLON & RECTUM | 13023 | 1.03 | 27037 | 1.14 | 28440 | 1.05 | 55532 | 1.13 |
| LIVER (PRIMARY) | 3086 | 0.92 | 6450 | 1.01 | 3082 | 0.92 | 6279 | 0.97 |
| TRACHEA, BRONCHUS, LUNG | 11160 | 1.02 | 20634 | 1.04 | 46060 | 1.01 | 79121 | 0.99 |
| BREAST (FEMALE) | 8279 | 1.07 | 15537 | 1.10 | 19634 | 1.08 | 36606 | 1.12 |
| THYROID | 327 | 0.98 | 672 | 1.07 | 571 | 1.04 | 1097 | 1.09 |
| BONES & JOINTS | 598 | 0.92 | 1145 | 0.94 | 816 | 0.93 | 1558 | 0.97 |
| BLADDER | 2681 | 1.11 | 5507 | 1.20 | 5461 | 1.08 | 10318 | 1.13 |
| BRAIN & OTHER C.N.S. | 2081 | 1.04 | 3503 | 0.95 | 5138 | 1.00 | 9130 | 0.99 |
| BENIGN & UNSPEC NEOPLASMS | 0 | - | 0 | - | 1512 | 1.01 | 2837 | 1.14 |

Table 1-B

Age at death: all

Electric Utilities < 1970

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.05* | 0.99 | 0.98 | 1.03 |
| ALL CANCER, EXCL LEUK | 1.00 | 1.01 | 1.01 | 0.98*** |
| HODGKIN'S DISEASE | 0.94 | 0.96 | 1.07 | 1.08** |
| OTHER LYMPHOMA | 1.06* | 1.06** | 0.96 | 0.98 |
| MULTIPLE MYELOMA | 1.07 | 0.97 | 0.91* | 1.00 |
| DIGESTIVE ORGANS | 0.99 | 1.01 | 1.03*** | 0.99 |
| STOMACH | 0.97* | 1.02 | 1.11*** | 1.02 |
| COLON & RECTUM | 1.01 | 1.02* | 1.01 | 0.98** |
| LIVER (PRIMARY) | 0.96 | 0.99 | 0.96 | 0.93*** |
| TRACHEA, BRONCHUS, LUNG | 1.02 | 1.04*** | 0.98 | 0.93*** |
| BREAST (FEMALE) | 1.03 | 1.02 | 1.00 | 1.00 |
| THYROID | 0.98 | 1.04 | 1.05 | 1.00 |
| BONES & JOINTS | 1.10 | 1.03 | 0.99 | 1.00 |
| BLADDER | 1.00 | 1.02 | 0.97 | 0.93*** |
| BRAIN & OTHER C.N.S. | 1.06 | 0.99 | 0.94* | 1.03 |
| BENIGN & UNSPEC NEOPLASMS | - | 0.92* | - | - |

*  : 0.01 < P <= 0.05
**  : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-C

Age at death: under 10 Electric Utilities 1970-74

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 996 | 1.06 | 2383 | 0.98 | 227 | 1.00 | 482 | 0.94 |
| ALL CANCER, EXCL LEUK | 921 | 0.94 | 2600 | 1.03 | 340 | 1.07 | 687 | 0.97 |
| HODGKIN'S DISEASE | 25 | 1.60 | 41 | 1.02 | 1 | 0.50 | 2 | 0.44 |
| OTHER LYMPHOMA | 131 | 0.99 | 309 | 0.90 | 29 | 0.91 | 65 | 0.90 |
| MULTIPLE MYELOMA | 0 | 0.00 | 2 | 2.00 | 3 | 12.30 | 0 | 0.00 |
| DIGESTIVE ORGANS | 43 | 0.86 | 127 | 0.98 | 21 | 1.23 | 36 | 0.96 |
| STOMACH | 1 | 0.47 | 4 | 0.72 | 3 | 6.65 | 1 | 1.02 |
| COLON & RECTUM | 9 | 1.66 | 14 | 0.99 | 1 | 0.70 | 5 | 1.64 |
| LIVER (PRIMARY) | 24 | 0.81 | 74 | 0.98 | 15 | 1.16 | 29 | 1.01 |
| TRACHEA, BRONCHUS, LUNG | 7 | 0.86 | 22 | 1.05 | 3 | 0.83 | 3 | 0.38 |
| BREAST (FEMALE) | 2 | 1.63 | 10 | 3.16 | 0 | 0.00 | 0 | 0.00 |
| THYROID | 2 | 2.14 | 4 | 1.61 | 0 | 0.00 | 0 | 0.00 |
| BONES & JOINTS | 36 | 1.01 | 108 | 1.18 | 13 | 1.27 | 21 | 0.91 |
| BLADDER | 8 | 1.43 | 16 | 1.10 | 2 | 2.17 | 3 | 1.47 |
| BRAIN & OTHER C.N.S. | 366 | 0.93 | 1054 | 1.04 | 109 | 0.97 | 245 | 0.97 |
| BENIGN & UNSPEC NEOPLASMS | 27 | 1.25 | 45 | 0.90 | 25 | 0.79 | 71 | 1.00 |

Table 1-C

Age at death: under 10 Electric Utilities 1970-74

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.09* | 1.06 | 0.96 | 0.95 |
| ALL CANCER, EXCL LEUK | 0.89** | 1.07 | 1.12 | 0.94 |
| HODGKIN'S DISEASE | 1.60 | - | - | - |
| OTHER LYMPHOMA | 1.00 | 0.97 | 0.90 | 0.98 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.90 | 1.26 | 1.49 | 1.06 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | - | - | - | - |
| LIVER (PRIMARY) | 0.80 | 1.08 | 1.41 | 1.10 |
| TRACHEA, BRONCHUS, LUNG | 0.78 | - | - | - |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 0.90 | 1.30 | 1.18 | 0.82 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 0.87* | 1.00 | 1.01 | 0.92 |
| BENIGN & UNSPEC NEOPLASMS | 1.53 | 0.83 | 0.56* | 1.15 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-C

Age at death: 10 to 19 — Electric Utilities 1970-74

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 469 | 1.01 | 1180 | 0.99 | 223 | 0.96 | 576 | 1.08 |
| ALL CANCER, EXCL LEUK | 883 | 1.00 | 2234 | 0.98 | 401 | 0.94 | 855 | 0.89 |
| HODGKIN'S DISEASE | 93 | 1.02 | 231 | 0.98 | 23 | 0.82 | 56 | 0.88 |
| OTHER LYMPHOMA | 143 | 1.09 | 317 | 0.95 | 58 | 0.96 | 119 | 0.86 |
| MULTIPLE MYELOMA | 0 | 0.00 | 0 | 0.00 | 1 | 2.68 | 3 | 3.51 |
| DIGESTIVE ORGANS | 50 | 1.16 | 113 | 1.03 | 19 | 0.90 | 34 | 0.73 |
| STOMACH | 1 | 0.32 | 3 | 0.38 | 1 | 0.92 | 1 | 0.43 |
| COLON & RECTUM | 15 | 0.91 | 48 | 1.15 | 8 | 1.11 | 6 | 0.39 |
| LIVER (PRIMARY) | 17 | 1.19 | 37 | 1.02 | 8 | 0.87 | 20 | 0.97 |
| TRACHEA, BRONCHUS, LUNG | 8 | 0.79 | 24 | 0.92 | 5 | 1.27 | 7 | 0.78 |
| BREAST (FEMALE) | 1 | 0.54 | 6 | 1.23 | 1 | 1.21 | 0 | 0.00 |
| THYROID | 1 | 0.42 | 9 | 1.47 | 0 | 0.00 | 3 | 1.65 |
| BONES & JOINTS | 134 | 0.81 | 439 | 1.04 | 66 | 0.87 | 151 | 0.87 |
| BLADDER | 0 | 0.00 | 5 | 2.45 | 0 | 0.00 | 1 | 1.56 |
| BRAIN & OTHER C.N.S. | 230 | 1.05 | 516 | 0.91 | 114 | 1.05 | 221 | 0.89 |
| BENIGN & UNSPEC NEOPLASMS | 27 | 1.52 | 42 | 0.99 | 22 | 0.96 | 53 | 1.01 |

Table 1-C

Age at death: 10 to 19 — Electric Utilities 1970-74

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.01 | 0.87 | 0.95 | 1.07 |
| ALL CANCER, EXCL LEUK | 0.99 | 1.06 | 0.94 | 0.91* |
| HODGKIN'S DISEASE | 1.03 | 0.96 | 0.78 | 0.90 |
| OTHER LYMPHOMA | 1.15 | 1.08 | 0.85 | 0.92 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 1.09 | 1.30 | 0.81 | 0.70 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | 0.72 | - | 1.17 | 0.35* |
| LIVER (PRIMARY) | 1.14 | 0.93 | 0.78 | 0.91 |
| TRACHEA, BRONCHUS, LUNG | 0.86 | - | - | 0.88 |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 0.78* | 1.02 | 1.07 | 0.84 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 1.08 | 1.15 | 0.99 | 0.97 |
| BENIGN & UNSPEC NEOPLASMS | 1.68* | 0.95 | 0.68 | 1.31 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-C

Age at death: 20 to 39 — Electric Utilities 1970-74

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 665 | 0.96 | 1660 | 0.96 | 474 | 1.09 | 982 | 1.03 |
| ALL CANCER, EXCL LEUK | 6104 | 0.99 | 15567 | 1.00 | 3248 | 0.98 | 7235 | 1.00 |
| HODGKIN'S DISEASE | 592 | 1.06 | 1481 | 1.05 | 231 | 1.06 | 489 | 1.01 |
| OTHER LYMPHOMA | 331 | 0.96 | 886 | 1.03 | 217 | 0.98 | 463 | 0.95 |
| MULTIPLE MYELOMA | 27 | 1.00 | 75 | 1.12 | 14 | 0.94 | 35 | 1.11 |
| DIGESTIVE ORGANS | 986 | 0.95 | 2718 | 1.04 | 453 | 0.93 | 994 | 0.95 |
| STOMACH | 182 | 0.84 | 535 | 0.99 | 67 | 0.82 | 153 | 0.88 |
| COLON & RECTUM | 493 | 0.97 | 1356 | 1.05 | 217 | 0.92 | 481 | 0.95 |
| LIVER (PRIMARY) | 116 | 1.10 | 266 | 1.01 | 67 | 1.25 | 109 | 0.97 |
| TRACHEA, BRONCHUS, LUNG | 463 | 0.95 | 1196 | 1.00 | 309 | 0.98 | 684 | 1.01 |
| BREAST (FEMALE) | 830 | 0.97 | 2202 | 1.02 | 500 | 0.97 | 1161 | 1.04 |
| THYROID | 24 | 1.17 | 61 | 1.18 | 13 | 1.57 | 23 | 1.27 |
| BONES & JOINTS | 126 | 1.12 | 260 | 0.92 | 80 | 1.18 | 142 | 0.95 |
| BLADDER | 30 | 1.13 | 56 | 0.84 | 7 | 0.68 | 30 | 1.34 |
| BRAIN & OTHER C.N.S. | 491 | 0.91 | 1306 | 0.96 | 310 | 0.98 | 688 | 0.98 |
| BENIGN & UNSPEC NEOPLASMS | 35 | 0.85 | 93 | 1.01 | 82 | 1.18 | 134 | 0.88 |

Table 1-C

Age at death: 20 to 39 — Electric Utilities 1970-74

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 0.99 | 1.06 | 1.14* | 1.08 |
| ALL CANCER, EXCL LEUK | 0.99 | 0.98 | 0.99 | 1.00 |
| HODGKIN'S DISEASE | 1.05 | 1.06 | 1.00 | 0.96 |
| OTHER LYMPHOMA | 0.94 | 1.05 | 1.04 | 0.92 |
| MULTIPLE MYELOMA | 0.96 | 0.96 | 0.96 | 0.96 |
| DIGESTIVE ORGANS | 0.94 | 0.96 | 0.98 | 0.93* |
| STOMACH | 0.88 | 0.90 | 0.93 | 0.90 |
| COLON & RECTUM | 0.97 | 0.97 | 0.97 | 0.92 |
| LIVER (PRIMARY) | 1.09 | 1.31 | 1.13 | 0.98 |
| TRACHEA, BRONCHUS, LUNG | 0.92 | 0.95 | 1.02 | 1.01 |
| BREAST (FEMALE) | 0.98 | 0.93 | 0.99 | 1.04 |
| THYROID | 1.11 | 1.25 | 1.46 | 1.08 |
| BONES & JOINTS | 1.25* | 1.35* | 1.07 | 1.07 |
| BLADDER | 1.49 | 0.50 | 0.59 | 1.64* |
| BRAIN & OTHER C.N.S. | 0.93 | 0.98 | 1.08 | 1.03 |
| BENIGN & UNSPEC NEOPLASMS | 0.87 | 1.39* | 1.46 | 0.90 |

* : $0.01 < P \leq 0.05$
** : $0.001 < P \leq 0.01$
*** : $P \leq 0.001$

Table 1-C

Age at death: 40 to 59 — Electric Utilities 1970-74

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 1599 | 0.96 | 4271 | 0.98 | 904 | 0.98 | 2020 | 0.97 |
| ALL CANCER, EXCL LEUK | 47765 | 1.00 | 125072 | 1.01 | 29393 | 0.97 | 68437 | 1.00 |
| HODGKIN'S DISEASE | 618 | 0.94 | 1811 | 1.06 | 211 | 1.07 | 478 | 1.07 |
| OTHER LYMPHOMA | 1582 | 1.09 | 3653 | 0.97 | 943 | 1.02 | 2161 | 1.02 |
| MULTIPLE MYELOMA | 516 | 0.98 | 1346 | 0.99 | 348 | 0.91 | 804 | 0.94 |
| DIGESTIVE ORGANS | 12751 | 0.99 | 34228 | 1.02 | 6485 | 0.99 | 15112 | 1.02 |
| STOMACH | 2241 | 0.91 | 6628 | 1.03 | 814 | 0.93 | 1983 | 1.02 |
| COLON & RECTUM | 5745 | 1.05 | 15163 | 1.05 | 2937 | 1.01 | 7018 | 1.06 |
| LIVER (PRIMARY) | 1256 | 0.98 | 3486 | 1.03 | 379 | 1.02 | 729 | 0.89 |
| TRACHEA, BRONCHUS, LUNG | 9339 | 0.98 | 23922 | 0.97 | 8381 | 0.92 | 20119 | 0.98 |
| BREAST (FEMALE) | 6665 | 1.00 | 17782 | 1.02 | 4166 | 1.01 | 9416 | 1.00 |
| THYROID | 126 | 0.81 | 452 | 1.10 | 60 | 0.95 | 127 | 0.89 |
| BONES & JOINTS | 277 | 1.01 | 710 | 0.99 | 89 | 1.03 | 180 | 0.92 |
| BLADDER | 709 | 0.97 | 2022 | 1.06 | 342 | 1.05 | 775 | 1.04 |
| BRAIN & OTHER C.N.S. | 1762 | 1.00 | 4546 | 0.99 | 1020 | 0.96 | 2417 | 0.99 |
| BENIGN & UNSPEC NEOPLASMS | 159 | 1.05 | 450 | 1.20 | 215 | 0.92 | 485 | 0.91 |

Table 1-C

Age at death: 40 to 59 — Electric Utilities 1970-74

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 0.97 | 1.02 | 1.03 | 0.99 |
| ALL CANCER, EXCL LEUK | 0.99 | 0.97*** | 0.97*** | 1.00 |
| HODGKIN'S DISEASE | 0.93 | 1.07 | 1.12 | 1.03 |
| OTHER LYMPHOMA | 1.13*** | 1.00 | 0.93 | 1.06* |
| MULTIPLE MYELOMA | 0.97 | 0.98 | 0.92 | 0.95 |
| DIGESTIVE ORGANS | 0.99 | 0.98 | 0.99 | 1.01 |
| STOMACH | 0.91*** | 0.93 | 1.00 | 1.01 |
| COLON & RECTUM | 1.04** | 0.98 | 0.98 | 1.03 |
| LIVER (PRIMARY) | 0.95 | 1.12 | 1.02 | 0.87*** |
| TRACHEA, BRONCHUS, LUNG | 0.97* | 0.92*** | 0.93*** | 1.00 |
| BREAST (FEMALE) | 1.00 | 1.01 | 1.01 | 0.99 |
| THYROID | 0.74** | 1.15 | 1.12 | 0.83 |
| BONES & JOINTS | 1.06 | 1.10 | 1.01 | 0.95 |
| BLADDER | 0.90* | 1.02 | 1.07 | 0.99 |
| BRAIN & OTHER C.N.S. | 1.00 | 0.96 | 0.96 | 1.00 |
| BENIGN & UNSPEC NEOPLASMS | 0.94 | 1.04 | 0.92 | 0.79*** |

* : $0.01 < P \leq 0.05$
** : $0.001 < P \leq 0.01$
*** : $P \leq 0.001$

Table 1-C

Age at death: 60 plus — Electric Utilities 1970-74

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 4625 | 0.96 | 11678 | 0.96 | 3787 | 0.95 | 8763 | 1.00 |
| ALL CANCER, EXCL LEUK | 123535 | 0.99 | 326417 | 1.03 | 105793 | 1.00 | 239992 | 1.03 |
| HODGKIN'S DISEASE | 719 | 0.93 | 2170 | 1.10 | 379 | 1.06 | 785 | 1.00 |
| OTHER LYMPHOMA | 3236 | 1.06 | 7412 | 0.97 | 3412 | 1.05 | 7337 | 1.02 |
| MULTIPLE MYELOMA | 1443 | 0.96 | 3812 | 1.01 | 1876 | 1.02 | 4068 | 1.01 |
| DIGESTIVE ORGANS | 47481 | 0.98 | 130579 | 1.05 | 32661 | 1.01 | 73616 | 1.04 |
| STOMACH | 9604 | 0.92 | 29101 | 1.07 | 4269 | 1.00 | 10138 | 1.10 |
| COLON & RECTUM | 22351 | 1.02 | 59569 | 1.07 | 16662 | 1.03 | 37033 | 1.05 |
| LIVER (PRIMARY) | 4525 | 0.94 | 12725 | 1.02 | 1534 | 0.98 | 3257 | 0.96 |
| TRACHEA, BRONCHUS, LUNG | 18924 | 0.97 | 47284 | 0.97 | 24927 | 0.96 | 57100 | 1.00 |
| BREAST (FEMALE) | 9310 | 1.00 | 24499 | 1.03 | 8330 | 1.04 | 19300 | 1.07 |
| THYROID | 491 | 0.98 | 1233 | 0.95 | 311 | 1.07 | 631 | 0.99 |
| BONES & JOINTS | 660 | 0.96 | 1859 | 1.05 | 271 | 1.02 | 579 | 1.00 |
| BLADDER | 4985 | 1.07 | 12846 | 1.08 | 3410 | 1.03 | 7667 | 1.08 |
| BRAIN & OTHER C.N.S. | 1511 | 1.04 | 3368 | 0.92 | 2019 | 1.01 | 4594 | 1.03 |
| BENIGN & UNSPEC NEOPLASMS | 324 | 1.00 | 791 | 1.03 | 794 | 1.06 | 1822 | 1.12 |

Table 1-C

Age at death: 60 plus — Electric Utilities 1970-74

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.00 | 0.96 | 1.00 | 1.05*** |
| ALL CANCER, EXCL LEUK | 0.98*** | 0.98*** | 1.02*** | 1.01 |
| HODGKIN'S DISEASE | 0.87** | 1.08 | 1.14* | 0.91* |
| OTHER LYMPHOMA | 1.10*** | 1.03 | 1.00 | 1.06*** |
| MULTIPLE MYELOMA | 0.93* | 1.02 | 1.08* | 1.00 |
| DIGESTIVE ORGANS | 0.97*** | 1.00 | 1.04*** | 1.01 |
| STOMACH | 0.89*** | 0.94** | 1.07*** | 1.04*** |
| COLON & RECTUM | 1.01 | 1.03*** | 1.03** | 1.00 |
| LIVER (PRIMARY) | 0.95** | 0.99 | 1.03 | 0.96* |
| TRACHEA, BRONCHUS, LUNG | 0.97*** | 0.94*** | 0.98** | 1.03*** |
| BREAST (FEMALE) | 1.01 | 1.01 | 1.06*** | 1.05*** |
| THYROID | 1.05 | 1.11 | 1.10 | 1.06 |
| BONES & JOINTS | 0.96 | 1.03 | 1.07 | 0.96 |
| BLADDER | 1.00 | 0.97 | 0.97 | 1.00 |
| BRAIN & OTHER C.N.S. | 1.08* | 0.95 | 0.95 | 1.12*** |
| BENIGN & UNSPEC NEOPLASMS | 1.01 | 1.00 | 1.07 | 1.10* |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-C

Age at death: all — Electric Utilities 1970-74

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 8354 | 0.97 | 21172 | 0.97 | 5615 | 0.97 | 12823 | 1.00 |
| ALL CANCER, EXCL LEUK | 179208 | 0.99 | 471890 | 1.02 | 139175 | 0.99 | 317206 | 1.02 |
| HODGKIN'S DISEASE | 2047 | 0.98 | 5734 | 1.07 | 845 | 1.05 | 1810 | 1.01 |
| OTHER LYMPHOMA | 5423 | 1.06 | 12577 | 0.97 | 4659 | 1.04 | 10145 | 1.02 |
| MULTIPLE MYELOMA | 1986 | 0.96 | 5235 | 1.01 | 2242 | 1.00 | 4910 | 1.00 |
| DIGESTIVE ORGANS | 61311 | 0.98 | 167765 | 1.04 | 39639 | 1.01 | 89792 | 1.04 |
| STOMACH | 12029 | 0.92 | 36271 | 1.06 | 5154 | 0.99 | 12276 | 1.08 |
| COLON & RECTUM | 28613 | 1.03 | 76150 | 1.07 | 19825 | 1.03 | 44543 | 1.05 |
| LIVER (PRIMARY) | 5938 | 0.95 | 16588 | 1.02 | 2003 | 1.00 | 4144 | 0.95 |
| TRACHEA, BRONCHUS, LUNG | 28741 | 0.97 | 72448 | 0.97 | 33625 | 0.95 | 77913 | 0.99 |
| BREAST (FEMALE) | 16808 | 1.00 | 44499 | 1.02 | 12997 | 1.03 | 29877 | 1.05 |
| THYROID | 644 | 0.94 | 1759 | 1.00 | 384 | 1.06 | 784 | 0.98 |
| BONES & JOINTS | 1233 | 0.97 | 3376 | 1.03 | 519 | 1.02 | 1073 | 0.96 |
| BLADDER | 5732 | 1.06 | 14945 | 1.08 | 3761 | 1.03 | 8476 | 1.08 |
| BRAIN & OTHER C.N.S. | 4360 | 1.00 | 10790 | 0.96 | 3572 | 0.99 | 8165 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | 572 | 1.03 | 1421 | 1.07 | 1138 | 1.03 | 2565 | 1.05 |

Table 1-C

Age at death: all

Electric Utilities 1970-74

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.00 | 0.98 | 1.01 | 1.04** |
| ALL CANCER, EXCL LEUK | 0.98*** | 0.98*** | 1.00 | 1.01 |
| HODGKIN'S DISEASE | 0.95 | 1.07 | 1.08 | 0.95 |
| OTHER LYMPHOMA | 1.10*** | 1.03 | 0.98 | 1.05*** |
| MULTIPLE MYELOMA | 0.94* | 1.01 | 1.05 | 0.99 |
| DIGESTIVE ORGANS | 0.98*** | 1.00 | 1.03*** | 1.01 |
| STOMACH | 0.89*** | 0.94*** | 1.06** | 1.03** |
| COLON & RECTUM | 1.02** | 1.03** | 1.02 | 1.00 |
| LIVER (PRIMARY) | 0.95** | 1.02 | 1.03 | 0.94*** |
| TRACHEA, BRONCHUS, LUNG | 0.97*** | 0.93*** | 0.96*** | 1.02*** |
| BREAST (FEMALE) | 1.00 | 1.01 | 1.04** | 1.03*** |
| THYROID | 0.97 | 1.12 | 1.11 | 1.01 |
| BONES & JOINTS | 0.98 | 1.09 | 1.06 | 0.95 |
| BLADDER | 0.99 | 0.97 | 0.98 | 1.00 |
| BRAIN & OTHER C.N.S. | 1.01 | 0.96 | 0.97 | 1.05** |
| BENIGN & UNSPEC NEOPLASMS | 1.01 | 1.03 | 1.02 | 1.00 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-D

Age at death: under 10 — Electric Utilities 1975-81

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 392 | 1.07 | 785 | 0.95 | 28 | 0.70 | 88 | 0.93 |
| ALL CANCER, EXCL LEUK | 411 | 1.01 | 929 | 1.03 | 63 | 1.02 | 123 | 0.85 |
| HODGKIN'S DISEASE | 11 | 1.75 | 12 | 0.86 | 0 | 0.00 | 0 | 0.00 |
| OTHER LYMPHOMA | 47 | 0.89 | 125 | 1.06 | 3 | 0.51 | 14 | 1.03 |
| MULTIPLE MYELOMA | 0 | 0.00 | 1 | 2.34 | 0 | 0.00 | 0 | 0.00 |
| DIGESTIVE ORGANS | 16 | 0.77 | 48 | 1.04 | 2 | 0.57 | 5 | 0.61 |
| STOMACH | 0 | 0.00 | 3 | 1.47 | 0 | 0.00 | 0 | 0.00 |
| COLON & RECTUM | 4 | 1.76 | 3 | 0.60 | 1 | 3.07 | 1 | 1.33 |
| LIVER (PRIMARY) | 10 | 0.80 | 31 | 1.12 | 1 | 0.38 | 4 | 0.65 |
| TRACHEA, BRONCHUS, LUNG | 4 | 1.16 | 8 | 1.05 | 0 | 0.00 | 0 | 0.00 |
| BREAST (FEMALE) | 0 | 0.00 | 2 | 1.70 | 0 | 0.00 | 1 | 1.87 |
| THYROID | 0 | 0.00 | 1 | 1.37 | 0 | 0.00 | 0 | 0.00 |
| BONES & JOINTS | 15 | 1.04 | 27 | 0.84 | 3 | 1.61 | 5 | 1.14 |
| BLADDER | 2 | 0.91 | 4 | 0.82 | 1 | 6.70 | 0 | 0.00 |
| BRAIN & OTHER C.N.S. | 167 | 1.05 | 363 | 1.02 | 33 | 1.52 | 39 | 0.77 |
| BENIGN & UNSPEC NEOPLASMS | 20 | 1.32 | 35 | 1.08 | 9 | 1.98 | 3 | 0.28 |

Table 1-D

Age at death: under 10 — Electric Utilities 1975-81

| Disease | Relative Risks: Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.11 | 0.82 | 0.64* | 0.97 |
| ALL CANCER, EXCL LEUK | 0.99 | 1.24 | 1.02 | 0.83 |
| HODGKIN'S DISEASE | 2.07 | - | - | - |
| OTHER LYMPHOMA | 0.81 | - | - | 0.94 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.71 | - | - | 0.56 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | - | - | - | - |
| LIVER (PRIMARY) | 0.62 | - | - | - |
| TRACHEA, BRONCHUS, LUNG | - | - | - | - |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 1.38 | - | - | - |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 1.03 | 2.02** | 1.47* | 0.75 |
| BENIGN & UNSPEC NEOPLASMS | 1.24 | - | 1.44 | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-D

Age at death: 10 to 19 — Electric Utilities 1975-81

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 196 | 0.96 | 434 | 0.94 | 40 | 0.91 | 87 | 0.82 |
| ALL CANCER, EXCL LEUK | 369 | 0.93 | 839 | 0.94 | 82 | 1.01 | 169 | 0.87 |
| HODGKIN'S DISEASE | 33 | 0.87 | 65 | 0.76 | 5 | 0.94 | 12 | 0.95 |
| OTHER LYMPHOMA | 56 | 0.98 | 110 | 0.85 | 7 | 0.62 | 25 | 0.92 |
| MULTIPLE MYELOMA | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| DIGESTIVE ORGANS | 14 | 0.68 | 57 | 1.23 | 8 | 1.89 | 8 | 0.79 |
| STOMACH | 0 | 0.00 | 3 | 0.88 | 1 | 4.56 | 0 | 0.00 |
| COLON & RECTUM | 7 | 0.86 | 21 | 1.16 | 1 | 0.73 | 3 | 0.92 |
| LIVER (PRIMARY) | 6 | 0.85 | 22 | 1.40 | 6 | 3.13 | 4 | 0.88 |
| TRACHEA, BRONCHUS, LUNG | 3 | 0.67 | 12 | 1.19 | 0 | 0.00 | 1 | 0.58 |
| BREAST (FEMALE) | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| THYROID | 1 | 0.97 | 2 | 0.86 | 0 | 0.00 | 1 | 2.74 |
| BONES & JOINTS | 75 | 1.03 | 156 | 0.95 | 13 | 0.91 | 33 | 0.96 |
| BLADDER | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| BRAIN & OTHER C.N.S. | 91 | 0.93 | 220 | 1.00 | 20 | 0.98 | 35 | 0.72 |
| BENIGN & UNSPEC NEOPLASMS | 9 | 0.73 | 25 | 0.91 | 1 | 0.38 | 2 | 0.31 |

Table 1-D

Age at death: 10 to 19 — Electric Utilities 1975-81

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.01 | 1.06 | 0.92 | 0.89 |
| ALL CANCER, EXCL LEUK | 0.99 | 1.23 | 1.13 | 0.93 |
| HODGKIN'S DISEASE | 1.15 | - | - | 1.19 |
| OTHER LYMPHOMA | 1.14 | 0.77 | 0.64 | 1.12 |
| MULTIPLE MYELOMA | - | - | - | - |
| DIGESTIVE ORGANS | 0.53* | - | - | 0.65 |
| STOMACH | - | - | - | - |
| COLON & RECTUM | 0.68 | - | - | - |
| LIVER (PRIMARY) | 0.59 | - | - | - |
| TRACHEA, BRONCHUS, LUNG | - | - | - | - |
| BREAST (FEMALE) | - | - | - | - |
| THYROID | - | - | - | - |
| BONES & JOINTS | 1.07 | 1.03 | 0.99 | 1.00 |
| BLADDER | - | - | - | - |
| BRAIN & OTHER C.N.S. | 0.94 | 1.43 | 1.14 | 0.72 |
| BENIGN & UNSPEC NEOPLASMS | 0.77 | - | - | - |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-D

Age at death: 20 to 39 — Electric Utilities 1975-81

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 312 | 0.98 | 621 | 0.87 | 81 | 0.84 | 228 | 1.00 |
| ALL CANCER, EXCL LEUK | 2736 | 0.98 | 5889 | 0.95 | 751 | 1.04 | 1673 | 0.97 |
| HODGKIN'S DISEASE | 216 | 0.92 | 503 | 0.94 | 45 | 1.02 | 104 | 1.00 |
| OTHER LYMPHOMA | 141 | 0.90 | 299 | 0.85 | 61 | 1.22 | 98 | 0.83 |
| MULTIPLE MYELOMA | 11 | 0.87 | 26 | 0.94 | 6 | 1.81 | 10 | 1.25 |
| DIGESTIVE ORGANS | 421 | 0.90 | 993 | 0.96 | 106 | 0.99 | 235 | 0.92 |
| STOMACH | 83 | 0.86 | 215 | 1.02 | 16 | 0.89 | 38 | 0.88 |
| COLON & RECTUM | 201 | 0.90 | 470 | 0.95 | 49 | 0.97 | 108 | 0.89 |
| LIVER (PRIMARY) | 45 | 0.90 | 100 | 0.91 | 9 | 0.72 | 37 | 1.23 |
| TRACHEA, BRONCHUS, LUNG | 210 | 0.92 | 485 | 0.97 | 77 | 1.16 | 153 | 0.96 |
| BREAST (FEMALE) | 358 | 0.91 | 768 | 0.90 | 104 | 0.91 | 293 | 1.07 |
| THYROID | 4 | 0.45 | 15 | 0.77 | 0 | 0.00 | 5 | 1.19 |
| BONES & JOINTS | 63 | 1.21 | 122 | 1.02 | 16 | 1.06 | 30 | 0.85 |
| BLADDER | 15 | 1.27 | 33 | 1.28 | 3 | 1.32 | 5 | 0.92 |
| BRAIN & OTHER C.N.S. | 221 | 0.92 | 480 | 0.90 | 66 | 0.97 | 142 | 0.88 |
| BENIGN & UNSPEC NEOPLASMS | 29 | 0.91 | 77 | 1.10 | 7 | 0.65 | 22 | 0.86 |

Table 1-D

Age at death: 20 to 39 — Electric Utilities 1975-81

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.13 | 0.88 | 0.87 | 1.15 |
| ALL CANCER, EXCL LEUK | 1.04 | 1.12* | 1.11* | 1.02 |
| HODGKIN'S DISEASE | 0.98 | 1.11 | 1.10 | 1.03 |
| OTHER LYMPHOMA | 1.08 | 1.54* | 1.32 | 0.96 |
| MULTIPLE MYELOMA | 0.84 | - | - | 1.27 |
| DIGESTIVE ORGANS | 0.95 | 1.16 | 1.12 | 0.97 |
| STOMACH | 0.86 | 1.09 | 1.10 | 0.85 |
| COLON & RECTUM | 0.94 | 1.20 | 1.04 | 0.99 |
| LIVER (PRIMARY) | 1.02 | 0.62 | 0.96 | 1.34 |
| TRACHEA, BRONCHUS, LUNG | 1.00 | 1.36* | 1.29 | 1.00 |
| BREAST (FEMALE) | 1.03 | 0.89 | 1.11 | 1.21** |
| THYROID | - | - | - | - |
| BONES & JOINTS | 1.18 | 1.18 | 0.97 | 0.77 |
| BLADDER | 1.03 | - | - | 0.68 |
| BRAIN & OTHER C.N.S. | 1.04 | 1.14 | 1.06 | 1.02 |
| BENIGN & UNSPEC NEOPLASMS | 0.81 | 0.82 | 0.57 | 0.80 |

* : 0.01 < P <= 0.05
** : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-D

Age at death: 40 to 59 — Electric Utilities 1975-81

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 678 | 0.99 | 1443 | 0.96 | 190 | 1.07 | 424 | 0.95 |
| ALL CANCER, EXCL LEUK | 20179 | 0.97 | 44156 | 0.97 | 5816 | 0.98 | 14933 | 1.01 |
| HODGKIN'S DISEASE | 249 | 1.01 | 513 | 0.93 | 29 | 0.87 | 89 | 1.06 |
| OTHER LYMPHOMA | 548 | 0.91 | 1220 | 0.91 | 178 | 0.99 | 428 | 0.95 |
| MULTIPLE MYELOMA | 257 | 1.05 | 521 | 0.97 | 80 | 1.04 | 199 | 1.04 |
| DIGESTIVE ORGANS | 4990 | 0.92 | 10739 | 0.90 | 1222 | 0.96 | 3163 | 1.00 |
| STOMACH | 900 | 0.88 | 1829 | 0.82 | 136 | 0.81 | 405 | 0.98 |
| COLON & RECTUM | 2065 | 0.92 | 4467 | 0.90 | 527 | 0.95 | 1421 | 1.03 |
| LIVER (PRIMARY) | 462 | 0.92 | 1037 | 0.94 | 67 | 0.89 | 167 | 0.90 |
| TRACHEA, BRONCHUS, LUNG | 4496 | 1.00 | 9994 | 1.01 | 1874 | 1.02 | 4805 | 1.05 |
| BREAST (FEMALE) | 2608 | 0.92 | 5826 | 0.93 | 762 | 0.96 | 1949 | 0.98 |
| THYROID | 57 | 0.92 | 130 | 0.95 | 11 | 0.94 | 21 | 0.72 |
| BONES & JOINTS | 112 | 1.04 | 260 | 1.10 | 16 | 1.10 | 34 | 0.93 |
| BLADDER | 344 | 1.14 | 674 | 1.02 | 71 | 1.18 | 153 | 1.01 |
| BRAIN & OTHER C.N.S. | 756 | 1.05 | 1661 | 1.04 | 198 | 0.99 | 498 | 1.00 |
| BENIGN & UNSPEC NEOPLASMS | 100 | 0.96 | 274 | 1.19 | 27 | 0.86 | 77 | 0.97 |

Table 1-D

Age at death: 40 to 59 — Electric Utilities 1975-81

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.03 | 1.11 | 1.08 | 1.02 |
| ALL CANCER, EXCL LEUK | 1.03** | 0.99 | 1.02 | 1.04*** |
| HODGKIN'S DISEASE | 1.10 | 0.85 | 0.85 | 1.09 |
| OTHER LYMPHOMA | 1.01 | 1.03 | 1.05 | 1.06 |
| MULTIPLE MYELOMA | 1.07 | 0.99 | 1.01 | 1.11 |
| DIGESTIVE ORGANS | 1.05** | 0.99 | 1.04 | 1.08*** |
| STOMACH | 1.10* | 0.83 | 0.91 | 1.14* |
| COLON & RECTUM | 1.06* | 0.96 | 1.04 | 1.11*** |
| LIVER (PRIMARY) | 1.01 | 1.06 | 0.99 | 0.93 |
| TRACHEA, BRONCHUS, LUNG | 1.02 | 1.02 | 1.05 | 1.05** |
| BREAST (FEMALE) | 1.00 | 0.98 | 1.04 | 1.06* |
| THYROID | 0.98 | 1.40 | 0.97 | 0.76 |
| BONES & JOINTS | 0.97 | 1.19 | 1.10 | 0.89 |
| BLADDER | 1.16* | 1.20 | 1.05 | 0.97 |
| BRAIN & OTHER C.N.S. | 1.02 | 0.99 | 0.98 | 0.98 |
| BENIGN & UNSPEC NEOPLASMS | 0.82 | 0.94 | 0.84 | 0.81 |

*  : 0.01 < P <= 0.05
**  : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-D

Age at death: 60 plus — Electric Utilities 1975-81

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 1729 | 0.97 | 3880 | 0.94 | 667 | 0.91 | 1793 | 0.96 |
| ALL CANCER, EXCL LEUK | 45615 | 0.95 | 106071 | 0.95 | 19613 | 0.98 | 51887 | 1.01 |
| HODGKIN'S DISEASE | 259 | 0.99 | 632 | 1.04 | 67 | 1.13 | 149 | 0.97 |
| OTHER LYMPHOMA | 1228 | 1.03 | 2587 | 0.93 | 583 | 0.94 | 1463 | 0.92 |
| MULTIPLE MYELOMA | 668 | 1.00 | 1480 | 0.97 | 356 | 0.98 | 914 | 0.99 |
| DIGESTIVE ORGANS | 15877 | 0.89 | 37232 | 0.91 | 5585 | 0.94 | 14876 | 0.98 |
| STOMACH | 3123 | 0.87 | 6999 | 0.84 | 697 | 0.91 | 1705 | 0.87 |
| COLON & RECTUM | 7158 | 0.89 | 17083 | 0.92 | 2813 | 0.96 | 7584 | 1.01 |
| LIVER (PRIMARY) | 1398 | 0.89 | 3385 | 0.94 | 252 | 0.85 | 694 | 0.92 |
| TRACHEA, BRONCHUS, LUNG | 8445 | 1.00 | 19264 | 0.99 | 5337 | 1.03 | 14203 | 1.06 |
| BREAST (FEMALE) | 3182 | 0.88 | 7587 | 0.91 | 1434 | 0.95 | 3738 | 0.97 |
| THYROID | 145 | 0.81 | 404 | 0.97 | 40 | 0.79 | 124 | 0.96 |
| BONES & JOINTS | 207 | 0.89 | 553 | 1.02 | 29 | 0.72 | 98 | 0.94 |
| BLADDER | 1628 | 0.97 | 3836 | 0.99 | 606 | 1.05 | 1552 | 1.04 |
| BRAIN & OTHER C.N.S. | 642 | 1.01 | 1439 | 0.98 | 358 | 0.93 | 1017 | 1.02 |
| BENIGN & UNSPEC NEOPLASMS | 219 | 1.02 | 474 | 0.94 | 81 | 0.77 | 240 | 0.89 |

Table 1-D

Age at death: 60 plus — Electric Utilities 1975-81

| Disease | Relative Risks: Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Befor |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.01 | 0.96 | 0.96 | 1.04 |
| ALL CANCER, EXCL LEUK | 1.01 | 0.98* | 1.04*** | 1.06*** |
| HODGKIN'S DISEASE | 0.93 | 1.12 | 1.21 | 0.99 |
| OTHER LYMPHOMA | 1.08* | 1.00 | 0.94 | 1.03 |
| MULTIPLE MYELOMA | 1.00 | 0.97 | 1.00 | 1.07 |
| DIGESTIVE ORGANS | 1.02 | 0.98 | 1.04** | 1.06*** |
| STOMACH | 1.07** | 1.07 | 1.02 | 0.99 |
| COLON & RECTUM | 1.01 | 0.98 | 1.07** | 1.07*** |
| LIVER (PRIMARY) | 0.97 | 0.97 | 0.95 | 0.97 |
| TRACHEA, BRONCHUS, LUNG | 1.05*** | 0.99 | 1.04* | 1.08*** |
| BREAST (FEMALE) | 0.97 | 0.99 | 1.07* | 1.06** |
| THYROID | 0.85 | 0.79 | 0.98 | 0.96 |
| BONES & JOINTS | 0.87 | 0.79 | 0.90 | 0.93 |
| BLADDER | 1.04 | 1.04 | 1.04 | 1.02 |
| BRAIN & OTHER C.N.S. | 1.01 | 0.90 | 0.98 | 1.08 |
| BENIGN & UNSPEC NEOPLASMS | 1.08 | 0.89 | 0.78 | 0.91 |

*  : 0.01 < P <= 0.05
**  : 0.001 < P <= 0.01
*** : P <= 0.001

Table 1-D

Age at death: all — Electric Utilities 1975-81

| | Before Startup | | | | After Startup | | | |
|---|---|---|---|---|---|---|---|---|
| | Study | | Control | | Study | | Control | |
| Disease | OBS | SMR | OBS | SMR | OBS | SMR | OBS | SMR |
| LEUKEMIA & ALEUKEMIA | 3307 | 0.99 | 7163 | 0.94 | 1006 | 0.92 | 2620 | 0.95 |
| ALL CANCER, EXCL LEUK | 69310 | 0.96 | 157884 | 0.96 | 26325 | 0.98 | 68785 | 1.01 |
| HODGKIN'S DISEASE | 768 | 0.97 | 1725 | 0.96 | 146 | 1.02 | 354 | 1.00 |
| OTHER LYMPHOMA | 2020 | 0.98 | 4341 | 0.92 | 832 | 0.96 | 2028 | 0.92 |
| MULTIPLE MYELOMA | 936 | 1.01 | 2028 | 0.97 | 442 | 1.00 | 1123 | 1.00 |
| DIGESTIVE ORGANS | 21318 | 0.90 | 49069 | 0.91 | 6923 | 0.94 | 18287 | 0.98 |
| STOMACH | 4106 | 0.87 | 9049 | 0.84 | 850 | 0.89 | 2148 | 0.89 |
| COLON & RECTUM | 9435 | 0.90 | 22044 | 0.92 | 3391 | 0.96 | 9117 | 1.01 |
| LIVER (PRIMARY) | 1921 | 0.90 | 4575 | 0.94 | 335 | 0.86 | 906 | 0.92 |
| TRACHEA, BRONCHUS, LUNG | 13158 | 1.00 | 29763 | 0.99 | 7288 | 1.03 | 19162 | 1.06 |
| BREAST (FEMALE) | 6148 | 0.90 | 14183 | 0.92 | 2300 | 0.95 | 5981 | 0.98 |
| THYROID | 207 | 0.82 | 552 | 0.96 | 51 | 0.79 | 151 | 0.92 |
| BONES & JOINTS | 472 | 0.98 | 1118 | 1.02 | 77 | 0.89 | 200 | 0.93 |
| BLADDER | 1989 | 1.00 | 4547 | 0.99 | 681 | 1.06 | 1710 | 1.04 |
| BRAIN & OTHER C.N.S. | 1877 | 1.01 | 4163 | 0.99 | 675 | 0.97 | 1731 | 0.99 |
| BENIGN & UNSPEC NEOPLASMS | 377 | 1.00 | 885 | 1.03 | 125 | 0.81 | 344 | 0.87 |

Table 1-D

Age at death: all

Electric Utilities 1975-81

Relative Risks

| Disease | Study Before vs. Control Before | Study After vs. Control After | Study After vs. Study Before | Control After vs. Control Before |
|---|---|---|---|---|
| LEUKEMIA & ALEUKEMIA | 1.04 | 0.98 | 0.95 | 1.04 |
| ALL CANCER, EXCL LEUK | 1.02*** | 0.99 | 1.04*** | 1.05*** |
| HODGKIN'S DISEASE | 1.01 | 1.06 | 1.07 | 1.03 |
| OTHER LYMPHOMA | 1.05 | 1.02 | 0.98 | 1.03 |
| MULTIPLE MYELOMA | 1.01 | 0.98 | 1.01 | 1.08 |
| DIGESTIVE ORGANS | 1.02* | 0.99 | 1.04** | 1.06*** |
| STOMACH | 1.07*** | 1.02 | 1.00 | 1.02 |
| COLON & RECTUM | 1.02 | 0.98 | 1.07** | 1.07*** |
| LIVER (PRIMARY) | 0.97 | 0.98 | 0.96 | 0.97 |
| TRACHEA, BRONCHUS, LUNG | 1.04*** | 1.00 | 1.05** | 1.07*** |
| BREAST (FEMALE) | 0.99 | 0.98 | 1.06* | 1.07*** |
| THYROID | 0.87 | 0.84 | 0.96 | 0.94 |
| BONES & JOINTS | 0.97 | 0.98 | 0.98 | 0.92 |
| BLADDER | 1.06* | 1.06 | 1.05 | 1.02 |
| BRAIN & OTHER C.N.S. | 1.02 | 0.98 | 1.02 | 1.01 |
| BENIGN & UNSPEC NEOPLASMS | 0.97 | 0.96 | 0.80* | 0.84* |

*  : 0.01 < P <= 0.05
**  : 0.001 < P <= 0.01
*** : P <= 0.001

## INDIVIDUAL FACILITY MAPS

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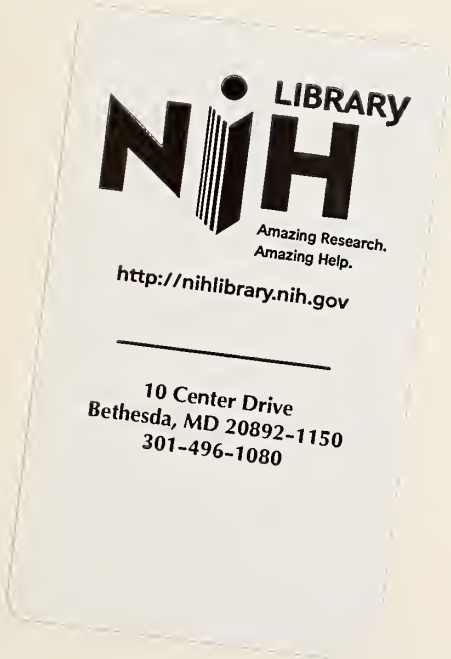
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